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THE OPERATION OF A SLOW SAND FILTER.

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[*Read March 9, 1898.*]

Mr. President and Members of the New England Water Works Association: Having been honored with a request to present before you a paper on the "Operation of a Sand Filter" I will endeavor to comply by narrating some of the experiences met in the effort, during the past seventeen years, to render the water of a sewage polluted river fit for domestic use by means of such an appliance.

The sand filter of my experience is located at Poughkeepsie, N. Y., a city of about 23,000 inhabitants, situated on the east bank of the Hudson River, about midway between its mouth and the head of navigation.

The construction of its system of water works was commenced in 1869 and completed in 1872. The commission entrusted with the work investigated every probable source of supply and arrived at the conclusion, which subsequent years have fully justified, that the Hudson River afforded the only assurance of an ample volume within the limits of reasonable cost. Their consulting engineer was the late James P. Kirkwood, of Brooklyn, N. Y., who had but recently investigated the filtration systems of Europe in the interest of the city of St. Louis, Mo. The city of St. Louis did not adopt the filtration system, but it was applied to the water supply of Poughkeepsie under Mr. Kirkwood's supervision and in accordance with his plans.

The Hudson River, at Poughkeepsie, has a drainage area of about 11,500 square miles. Within this area is a total population of about 1,000,000 and an urban population of about 500,000. Fifteen miles above Poughkeepsie, on the west shore, is the city of Kingston containing about 23,000 inhabitants. Forty miles above, on the east shore, is the city of Hudson, containing about 10,000 inhabitants. Seventy miles above, on the west shore, is the city of Albany with about 96,000 inhabitants and, above Albany, a total urban population of about 300,000. A short distance above Poughkeepsie, on the same side of the river, is located one of the New York State Hospitals for the Insane. The patients and attendants make a population of about 1,500 or upwards. The institution is completely sewered and the outfall is in the Hudson River 2,797 feet above the intake of the Poughkeepsie water works. The ebb tidal currents flow directly from this outfall past the intake. The central sewer outfall of the Poughkeepsie system discharges into the river 6,124 feet south of the water works intake, and the flood tidal currents, from the outfall, pass far above the intake but nearer the center of the river. The width of the river at the water works intake is about 2,400 feet with a nearly uniform depth of 50 feet, the shores being quite bold.

The pumping plant is located at the edge of the river. The filtration plant, as originally constructed, is located about 500 feet easterly and about 28 feet above mean high water in the river. This plant consists of a settling basin 25 feet by 60 feet in plan and 12 feet deep. The bed is 200 feet long by 150 feet wide, divided longitudinally into two sections by a wall in the center. The walls are vertical, of rubble masonry, and 12 feet in height from coping to top of concrete bottom.

The filtering materials occupy one half the depth, comprising, beginning at the bottom, 24 inches of coarse broken stones, 6 inches two-inch gravel, 6 inches one-inch gravel, 6 inches one-half-inch gravel, 6 inches one-quarter-inch gravel and 24 inches of sand. A main drain, of dry rubble 2 feet by 2 feet in cross section, extends longitudinally through the center of each section and two lateral drains of same dimensions traverse each section at right angles to the main drain.

A gate is placed at the outlet of each main drain, opening into an intermediate chamber 6 feet wide by 88 feet long and 16 feet deep,

from which the filtered water passes, over a weir, into a filtered water basin 88 feet long by 28 feet wide and 17 feet deep. From this basin the filtered water passes to the main pumping engine and thence to the distributing reservoir.

The distributing reservoir has a capacity of 12,000,000 gallons or a practical maximum supply of seven days.

The filter bed was put in operation in 1872. In 1874 an attempt was made to substitute subsidence in the distributing reservoir for filtration and the annual report for that year states that "The use of these beds has been abandoned except as may be occasionally required, when from the stage of the river the water may be unusually turbid." In the year 1875 the bed was in use about six months. In the year 1876 the annual report states they "Were in almost constant use." In the report for 1877 it is stated "The entire supply for this year was filtered." In the report for 1878 the volume filtered is the entire volume pumped, and it is added "The consumers accustomed to drink filtered water will accept nothing else, nor will they consider any circumstance, or complication of circumstances as offering any excuse for their nonuse." In the report for 1879 and 1880 the volumes filtered are the entire volumes pumped. The attempt to abandon the filter bed was not successful.

When I assumed charge of the works, in January, 1881, I found the bed not in use owing to a heavy coating of ice which rendered cleaning difficult. I at once caused the ice to be removed and the bed cleaned and put in operation. From that day I have not at any time seen the water of the river, judging from appearance alone, in fit condition for domestic use without some effort at purification. At that time bacteriological examinations of water supplies were unknown and but few chemical examinations had been made of the Poughkeepsie water; nevertheless I was impressed with the belief that that filter bed, in its best possible condition, was essential to the satisfactory quality of the water supplied to the city and upon that principle have based all action relative thereto, and have allowed no water to be supplied to the city without passing through it.

From various causes the river water has been much more heavily charged with mud and silt at all seasons, during the past eight or ten years, than previously. The normal rate of filtration, that is,

the water pumped from the clear water basin, prior to 1893, was 4,500,000 gallons per acre per twenty-four hours. Since 1893 the rate has been 5,000,000 gallons, or over, per twenty-four hours, per acre. The head, or difference of level between the surface of the water on the bed and that in the intermediate filtered water chamber, required to obtain this rate varied according to conditions, from 1 foot to 6 feet and, in extreme cases, it has increased to 7 feet or even 8 feet or more. During the last six or eight years the endeavor has been to make 4 feet the maximum.

The word "conditions" has a very broad significance to one who has been obliged to meet them. To understand this it must be borne in mind that there was on the one hand, among the consumers of water, a lingering impression, occasionally expressed, that the filter was not in use, and, on the other hand, my firm conviction that the constant use of the filter was a sanitary necessity and a firm determination that no unfiltered water should be pumped to the city.

A feature of this bed was a set of six 6-inch cast iron pipes, in each section, one being set vertically over each end of the main drain and the outer end of each lateral. They were open at each end and extended from the top of the drain nearly to the top of the side walls. The purpose of these pipes, evidently, was to provide an exit for the air in the lower portion of the bed when it was being filled by water flowing on the top and thereby prevent disturbance of the sand. I discovered after a time, however, that a practical use was made of them not altogether intended by the designer. I noticed that after reaching nearly the limit of head the bed would sometimes seem to run for a disproportionate time without material increase.

Upon examination and inquiry I found that the night engineer, and not infrequently the day engineer, would, in order to delay the cleaning of the bed, allow the water to rise and overflow these ventilators thus admitting an appreciable volume of unfiltered water to the drains below and relieving the bed. This practice was prohibited at once and a close watch maintained to prevent its recurrence.

During the years 1881 to 1883 the water of the river was much clearer than I have seen it since and, consequently, the work of the bed was less. It was the practice to "clean" the bed by removing from the surface of the sand the silt left by the water in passing

through. This was done whenever the bed failed to pass enough water under the given limit of head. The work was done by men with square pointed shovels who "skimmed" the slimy coat from the sand and deposited it in wheelbarrows which were wheeled by other men and deposited at the side of the bed. Still other men threw the deposit to the bank above. When the bed was new this was sufficient, but when I assumed charge it was not sufficient and it was the practice, after skimming, to loosen the sand with garden forks and then rake the surface over. This would not be done at every cleaning, but it soon became necessary to do it at every cleaning; and, after a time, even this was insufficient to enable the water to pass through readily but it would require from twelve hours to forty-eight hours after cleaning, for the bed to deliver the normal rate. In the construction of this bed no provision was made for drawing the water from above the surface of the sand when it became necessary to clean it. It was necessary, therefore, for the water to filter through before the work of cleaning could be commenced. In 1885 the condition of the filtering material had become such that forty-eight hours were required, after pumping ceased, to drain the sand so that cleaning could begin.

Prior to this time it had been the practice to replace the sand on the bed when a depth of about 6 inches had been removed in cleaning. Once only a depth of 10 inches had been removed. Below this depth the filtering material had not been disturbed since construction. Under the conditions mentioned it will be observed that a period of five days would be required from the time pumping on the bed ceased, in order to prepare for cleaning, to the time of obtaining normal flow from the bed after cleaning, namely, two days for draining, one day for cleaning and two days for obtaining normal flow.

At such a time if a storm, lasting two or three days, should occur to prevent cleaning the effect will be readily understood.

On the fourth day of January, 1886, a severe storm occurred as the bed was being cleaned and stopped the work when about two-thirds done. The rain was succeded by a muddy state of the river water previously unknown. In addition to this a period of severe cold set in which caused a large increase of consumption amounting in some days to nine-tenths of the full capacity of the pumping engine. The bed was filled to the coping and forced to its utmost,

but was unable to filter the full amount of daily consumption and the balance overflowed through the ventilating pipes, before mentioned, unfiltered, rendering the water delivered to the city very roily and causing great complaint. By constant pumping it required nearly three weeks to store sufficient water in the reservoir to permit the pumps to stop long enough to clean the bed and, when it was again cleaned its efficiency was but little improved. The sand pores had become so filled as to render it, under the water pressure necessary, like a mass of compact loam and almost as impervious to water. It thus became necessary, at once, either to remove the sand entirely and replace it with new, or after removing the old sand to wash and replace it. The latter course was decided upon and, accordingly, the entire body of sand was removed, to the gravel, and washed and replaced. The work was commenced in the latter part of March and completed the latter part of October, the bed being in continuous use meanwhile. A thickness of from 1 inch to 2 inches of sand was removed at a time and washed and placed in a pile. Then another, equal thickness, and so on. When the sand had been removed to within about 3 inches of the gravel the east section of the bed was shut off, the remainder of the sand removed from it, and washed, and the full depth of the washed sand replaced on this section.

During this time all the water pumped to the city was filtered through the west section. The west section was then shut off and the process repeated there. When the work of replacing was completed on both sections the bed was, apparently, in as good condition as a new bed. From this time the sand removed in cleaning, and washed, was not replaced as frequently as heretofore.

No sand was replaced until 1890 when, the sand remaining on the bed, about 6 inches in depth, was removed and washed and all was replaced as before. In 1893 the sand removed and washed during the previous three years was replaced on the bed together with about 400 cubic yards of new sand. In 1894 about 300 cubic yards of new sand was added and about the same quantity of old sand replaced making a depth of about 7 inches. In 1897 all of the sand on the bed was removed and wasted and new sand to the depth of 30 inches put on the bed.

One of the worst experiences occurred during the month of April, 1895. A heavy rain, on the 8th and 9th, brought down a charge of red mud and silt which stopped filtration. The pumps

were stopped on Thursday morning, the 11th, with nearly 14 feet of water in the reservoir. Allowing forty-eight hours for draining the bed we expected to clean on Saturday. On Saturday, however, it rained heavily; also a part of Sunday, so that no cleaning could be done until Monday, the 15th; but, even then, the bed was not sufficiently drained, owing to the rains of Saturday and Sunday. A force of men was put on and urged to their utmost and the bed cleaned and pumping to the reservoir started at seven o'clock in the evening, with less than 4 feet in the reservoir. Since it is impracticable to draw from the reservoir below 3 feet we had but 1 foot available, or twelve hours supply, when pumping began. The river being still very muddy we were compelled to stop pumping on Saturday morning, the 20th, after running four and one-half days. The bed was cleaned on Monday, the 22nd, and pumping began with less than 3 feet available in the reservoir. We were again obliged to stop on Saturday morning, the 27th, after running four and one-half days and clean on Monday, the 29th, starting the pumps with less than 3 feet available in the reservoir, so that three times during that month, we were in such condition that a rain storm of twenty-four hours would have compelled us to pump unfiltered water. We were obliged to clean the bed again on the 6th of May, making four times in five successive weeks, an experience unequaled before or since.

One of the great hindrances to the operation of this bed has been the growth of a species of green, filamentous, algæ on the surface of the sand. It does not develop in every year nor at the same time in the year. It sometimes begins in the latter part of May and sometimes not until September. It usually disappears with heavy frost. Its development begins in small round patches on the surface of the sand and continues with greater or less rapidity, according to temperature and condition of the water, until the entire surface is covered as with a blanket and the passage of water is entirely stopped. It has been known to develop on the clean sand and entirely stop filtration within seven days from cleaning. An essential condition for its rapid growth is clear sunlight. It will not develop in the dark and very little in the shadow of any object. All the basins, as constructed, were open to the sunlight. Much trouble was experienced from the growth of the same species of algæ in the clear water basin. In 1891 this basin was covered so as to exclude the light and no trace of algæ has been seen in it since. When filtration

is stopped from this cause there is no alternative but to drain the bed and clean in the usual way. The algæ cannot be removed under water. When the bed is drained and the algæ is allowed to dry it will cohere and roll up like a piece of paper. But touched with a shovel or other appliance for its removal, under water, it instantly flies in all directions in minute particles which immediately settle upon the sand and commence development vigorously on their own account. It has sometimes happened that the delivery of the bed has commenced to decrease, from algæ growth, within forty-eight hours after its removal. These extreme cases are, however, of rare occurrence. As this development always occurs during one of the seasons of greatest consumption of water it has sometimes taxed us to the utmost to maintain the supply of filtered water. I have never observed that its presence imparted either odor or taste to the filtered water.

During the last eight or ten years the frosts of winter have greatly hindered the maintenance of the bed in proper working condition. As before mentioned the river water has been much more turbid during this later period and it has seemed much more difficult to catch a thaw at the right time, and of sufficient duration, to enable the bed to be properly cleaned. In order to clean in the winter the first operation is to remove the ice. This will vary from 10 to 20 inches in thickness and we have removed some 28 inches thick, though that thickness is very seldom attained and then does not extend over the entire surface. In removing the ice the bed is filled to the coping, and the ice cut in pieces and hauled out by men. The operation requires about a week, more or less, depending upon the thickness of ice and the number of men employed. When the ice has been removed, pumping is stopped and the bed drained. If we have struck a favorable thaw, and, if during the forty-eight hours or more required to drain the bed no frost occurs and none occurs until the bed is cleaned, all is well and the bed will probably be in good order. It, however, more frequently occurs that 2 or 3 inches of ice forms while the bed is being drained.

We have sometimes removed the ice and drained the bed without frost, and early in the morning of the day of cleaning, a sudden drop in temperature occur that would freeze the sand and stop the work before it was completed. It sometimes happens that we are unable to foresee the failure of the bed in time to remove the ice owing to a sudden change in the character of the river water. In

such cases an effort is made to clean by lowering the ice on the sand, breaking it up, turning over the pieces and cleaning underneath. This is very unsatisfactory and only undertaken in emergencies. A sudden drop of temperature will sometimes stop even this operation before it is completed. In February, 1893, the bed suddenly failed with about 10 or 12 inches of ice on the surface and low water in the reservoir. It was impossible to continue and the bed was drained and the ice lowered to the sand. As much ice as possible was removed from one section while the bed was being drained. The work of cleaning was commenced, but before two-thirds of the section from which the ice had been removed, had been cleaned, the sand froze to such an extent that the work was stopped. There were but 5 feet of water in the reservoir and I decided to turn on the water and get what we could from the bed, fully expecting to be compelled to pump direct from the river within the next twenty-four hours. To my surprise, on going to the bed the next morning, I found it delivering its normal flow. The ice, on the section from which none had been removed, had settled evenly upon the sand and the severe cold had frozen the sand to the under side so that when the ice arose with the inflowing water it carried about one inch of sand from the entire surface of that section with it. It is not a method of cleaning to be recommended but it delivered us at the only time in my experience that the elements were in complete mastery. It is very rare, however, that all the conditions would be favorable to such action.

The under surface of the ice must be even, the surface of the sand even, the thickness of the ice sufficient to lift the sand and not enough to protect the sand from cold and the cold intense enough to freeze the sand under the ice. All of these conditions must occur together, which is very seldom the case.

In cleaning the bed, as before described, from one-quarter inch to one-half inch of sand was removed under normal conditions. In cases of frost the depth would be increased, sometimes to 2 inches or more. The labor required, under normal conditions, was one man for each 150 square feet of surface cleaned per hour, including wheeling and elevating to bank. As the sand is in use it becomes, in time, coated with a gelatinous film, throughout its depth. The finer silt also extends, in continually decreasing quantity, for a considerable depth below that removed by cleaning. The pressure to maintain a given flow, with the surface clean, gradually in

creases. Consequently, the pressure throughout increases, until, after a sufficient time, the water will not pass through even after cleaning and it becomes necessary to loosen the sand. This is done by the use of garden forks, as before mentioned, which are pressed into the sand a sufficient depth, vertically, and the top of the handle drawn backward sufficiently to loosen the sand in front of it.

At first the forks need enter but 3 or 4 inches but the necessary depth gradually increases until the full length of the fork is used and even this is not sufficient and the entire body of sand must be removed and washed or renewed as was the case in 1886. After the sand is loosened the surface is raked over evenly with a garden rake. Forking and raking requires about one man to each 500 square feet of surface per hour.

Under the foregoing conditions of sand and pressure, the sand will sometimes become so compact and hard that a considerable force is required to press the fork into it, and the tramping of men on the surface makes no impression. The time required for a filter to attain the condition referred to as occurring in 1886 would, of course, depend upon the rate of filtration and the character of the applied water. The period of constant use had been about ten years previous to 1886. Subsequent to that the sand was all removed and replaced at the end of four years, in 1890, before such condition had attained. Subsequent to that the entire body was not removed until 1897, a period of seven years, when the same conditions occurred and it would have been impossible to complete the year. The most favorable conditions for cleaning are fair, mild weather, not cold or hot, with the sand slightly moist. In the heat of summer, under a glaring sun, the sand sometimes becomes baked to a depth of nearly an inch compelling the removal of a depth greater than would be necessary, were this not the case, thus increasing the expense. Greater care is required in cleaning as the bed grows older. The shovels should be lifted on the return stroke and not drawn backward on the sand, particularly, if the sand is moist. When the bed is to be forked and raked this is not essential. When the bed is new the only effect of a shower of rain, during cleaning, is to delay the work while the shower lasts, but if the bed has become clogged to any extent, even if it has not been necessary to loosen with forks, a heavy shower will so compact the surface as to necessitate recleaning the portion that has been cleaned or loosening it with rakes. If heavy rain falls upon a por-

tion that has been forked and raked it will be necessary to repeat both the forking and raking before the delivery will be satisfactory. The effect of a fall of snow, during cleaning, is to increase the labor and expense and, if the snow is moist or melting, and the sand at all clogged, will require the removal of a greater thickness of sand.

In 1886 two bridges were constructed, one spanning each section of the bed. These bridges were movable, laterally, lengthwise of the bed, upon rails laid upon the coping. From the bridges platforms were suspended a little above the surface of the sand. In cleaning the men stood upon the platforms, scraped the surface of the sand and deposited the scrapings upon the platforms.

When about one-third of the bed had been cleaned the bridge, with its load, was moved to one end of the bed and the load thrown upon the bank. By this method there was no wheeling or tramping, whatever, upon the sand. One man, by this process, would clean 240 square feet of surface per hour, under normal conditions. For two or more years all the cleaning was done by two men. One section of the bed being used while the other was being cleaned.

The two men would clean one section in three days. This method was abandoned chiefly because it was impracticable to so regulate the draft upon the section in use as to avoid overworking it and hastening its clogging. There was a material saving in cost of cleaning by the use of these bridges, but in the construction of the new bed, in 1896, owing to the increased cost of construction necessary for their use, this feature was omitted. In 1897, the timber work of the bridges having decayed to such an extent as to require renewal, their use was discontinued for the sake of uniformity of operation and a better appearance of the plant.

We have now returned to the original method of cleaning.

Several methods have been used for washing sand. The one in use when I assumed charge was to cause the sand to pass over two inclined troughs, each about 12 feet long.

Near the upper end of the first trough the sand was met by small streams of water issuing from a perforated pipe under a pressure of about 100 pounds per square inch. The inclination of the troughs was such that the water carried the sand down and the force of the small jets, with the attrition of the particles during the flow, separated the silt from the sand. The water and sand were discharged into a box or tank, the sand settling to the bottom and the water

flowing off at the top carrying the silt with it. Between the lower end of the upper trough and the upper end of the lower one, was a screen through which all the sand passed on its way down. Four men were employed who washed less than 3 cubic yards per day at an average cost of about $2.38 per cubic yard. The washing was very efficient. This system was changed by increasing the number of troughs and dispensing with the services of two men thereby reducing the cost to about $1.47 per cubic yard. The work was carried on from April to December. In 1886 a trough 240 feet long was constructed and an additional supply of water taken from the settling basin. Five or six men were employed and about 2,000 cubic yards washed from March to September, at a cost of about 61 cents per cubic yard.

This method was continued, with a less number of men, depending upon the quantity to be washed, for several years. The work done by this arrangement was not altogether satisfactory, and, in 1892, a machine was put in operation consisting of a circular tank in which was a vertical, hollow shaft with perforated arms projecting horizontally from the bottom. This shaft was made to revolve slowly by means of a water motor, the water from which passed down through the hollow shaft and out through the perforated arms. The sand was placed in the tank and agitated by the revolving arms while the water flowed up through the sand and off at the top of the tank carrying away the sand and silt. The sand, when sufficiently washed, was discharged through a valve at the bottom of the tank. The work done by this machine was very satisfactory except that it was difficult to separate the leaves and algæ, particularly the latter. The cost, by this method, was about 64 cents per cubic yard. In 1895 and 1896 a single jet washer was used. By this plan the cost was reduced to about 54 cents per cubic yard. For several years the work has been done mainly by two regular employees, together with other work, and the quantity washed in a given time, with a given quantity of water, would depend upon the diligence of the men. The figures given are for ordinary work. In November, 1897, in washing and replacing the sand removed from the new bed, since it was put in operation in December, 1896, a double jet of much greater capacity was used. The sand and water from the first jet was discharged into a tank from which the water and silt flowed off at the top while the sand passed through a valve in the bottom into the second jet. From this jet the water and sand were transported

about 130 feet to a tank over one corner of the bed. The water and remaining silt flowed off from the top of this tank and the sand discharged through a valve in the bottom on the bed.

A little over five cubic yards of sand were washed and delivered on the bed, per hour, by this means. The total cost of labor at eighteen cents per hour, for washing and delivering on the bed, was 24 cents per cubic yard. Cost of water three cents per cubic yard. Total 27 cents per cubic yard. The quantity of water used was eighteen times the quantity of sand. The work was well done.

The water used was filtered water taken from the force main.

The total quantity of sand washed was 325 cubic yards. The number of hours worked was sixty.

No examinations, chemical or otherwise, for the determination of the efficiency of the bed, were made for several years after its construction. In November, 1877, an analysis was made by the late Prof. W. R. Nichols of the Massachusetts Institute of Technology. Twelve years later, in November, 1889, an analysis was made by Dr. T. M. Drown, then of the above mentioned institute; also one in 1891. The results of these three analyses, in parts per 100,000 of albuminoid ammonia, before and after filtration, also the percentage of reduction of albuminoid ammonia, of free ammonia and total solids, are as follows:

	Albuminoid Ammonia. Parts in 100,000.				
			Percentage of Reduction.		
Date.	Unfiltered Water.	Filtered Water.	Alb. Am.	Free Am.	Tot. Sol.
November, 1877	.0197	.0139	29	30	24
November, 1889	.0198	.0130	34	68	22
November, 1891	.0153	.0100	35	100	28

During the fourteen years from November, 1877, to November, 1891, the materials composing the bed had not been disturbed except by washing and replacing the sand. No new sand had been added. These analyses show no deterioration in efficiency, but rather, a material increase, during that period.

The results of a series of six analyses, made by Dr. Drown in June, 1893, showed a percentage of reduction by filtration, as follows:

Albuminoid ammonia	38.2 per cent.
Free ammonia	97. "
Nitrogen, as nitrites	96. "
Oxygen consumed	29. "
Nitrogen, as nitrates (increased)	40. "

Ordinarily, little or no effect is produced upon the color of the river water by passing through this filter, though one analysis by Dr. Drown, showed a reduction of discoloration as great as 60 per cent as the result of filtration.

Bacteriological examinations, three in number, made by Dr. Drown in November and December, 1891, showed percentages of removal, highest 97.7 per cent, lowest 92.4 per cent, average 94.9 per cent. An examination by Dr. Drown in January, 1892, showed percentage of removal 82.1 per cent; and in December, 1892, 91.8 per cent.

In 1895 eight bacteriological examinations were made by D. B. Ward, M. D., of Poughkeepsie, from April to December, showing an average removal of 93.8 per cent, with maximum of 98.6 per cent in June and minimum of 85.9 per cent in October. On February 14, 1896, an examination by Dr. Ward showed only 31 per cent removed; and in February 24th, but 37 per cent removed.

The death rate from typhoid fever has varied materially during the past 18 years, as will appear from the following table showing the population, in each year, from 1880 to 1897, both inclusive, as estimated from the ratio of increase in the census returns of 1890 over those of 1880, together with the number of deaths, from that cause in each year, and the number per 10,000:

Year.	Estimated Population.	No. of Deaths from Typhoid Fever.	No. of Deaths per 10,000.
1880	20,200	12	5.9
1881	20,400	10	4.9
1882	20,600	22	10.6
1883	20,800	9	4.3
1884	21,000	11	5.2
1885	21,200	11	5.1
1886	21,400	4	1.8
1887	21,600	5	2.3
1888	21,800	5	2.2
1889	22,000	6	2.7
1890	22,200	6	2.7
1891	22,400	9	4.
1892	22,600	13	5.7
1893	22,800	22	9.6
1894	23,000	15	6.5
1895	23,200	10	4.8
1896	23,400	5	2.1
1897	23,600	11	4.6
			Average. 4.72

There appears to be no definite relation between the condition of the filter bed and the death rate from typhoid fever, except that the greatest number of deaths, from this cause, occur from January to April, when the efficiency of the bed is the lowest. In 1886 the condition of the bed was, certainly, the worst of any year of the eighteen under consideration, yet, the rate, 1.8 per 10,000, was the lowest of any year in that period. It is probable that the bed was not in as good order in February, 1893, when the rate was 9.6 per 10,000, as in 1892 or 1894, when the rate was much lower; it was certainly, however, in no better condition in 1886 than in 1892 and 1894. Of course the want of frequent bacteriological examinations deprives us of accurate knowledge, but these are the facts so far as they can be known without them. During the last six or eight years a higher rate of filtration has prevailed owing to increased leakage in the filter basin and the introduction of a pumping engine of greater capacity.

In 1896 an additional filter bed was constructed having an area equal to the old bed, thus doubling the filtering area. This bed consists of a single basin having a length, inside of walls, of 260 feet and width of 114 feet. Total area 29,640 square feet. The clear depth of the basin from the top of the coping to the surface of the concrete bottom, is 10.3 feet. This bed adjoins the old bed on the east and the side walls consist of rubble masonry laid in Rosendale cement mortar, faced with a brick wall laid in Portland cement mortar. The inner faces of the walls are vertical. The bottom is of concrete.

A main drain, of brick masonry, sunken below the surface of the concrete, extends longitudinally through the center of the basin. Lateral drains of 6-inch tile pipes are laid on the concrete bottom at right angles to the main drain, and 10 feet and 3 inches apart between centers. These lateral drains are covered with 2-inch broken stone. The spaces between the laterals are filled, to a depth of 10 inches, with 2-inch broken stone and 1-inch gravel. Above this is a layer of one-half inch gravel 8 inches thick, and above this, a layer of one-quarter inch gravel 6 inches thick; the total thickness of the gravel layers being 24 inches. Above the gravel is the filtering sand 31 inches in thickness. The water for this bed is taken from the settling basin of the old bed. The main drain discharges into a delivery well, 6 feet by 8 feet, on the out-

side of the north wall of the basin. In this well is a weir of cast iron, sliding in vertical grooves, by means of which the working head may be regulated. From this well the filtered water is conducted to the filtered water basin of the old bed.

The supply and delivery are controlled by gates so that the bed may be cut off at will. The sand and gravel, for this bed, were obtained from a bank at Hempstead Harbor, on Long Island.

They were screened and washed at the bank and delivered along side our dock on scows from which they were delivered to the bed by carts. Water was let on this bed on December 17th, 1896. From the beginning of 1897, nearly all the work devolved upon this bed owing to the clogging of the old one.

About the first of June, 1897, the old bed was shut off and the work of repair commenced. The sand remaining thereon was entirely removed and wasted. The gravel and broken stones, forming the lower portion of the bed, originally 4 feet in depth, was excavated around the outer wall, to the bottom, of sufficient width to permit working. The joints of the rubble masonry composing the side walls were cut out and filled with mortar composed of Trinidad asphalt and sand, applied hot and driven in with hammers. A trench about 3 inches wide and 4 inches deep was cut in the concrete bottom, next the wall, which was filled with the same mortar rammed solid. The surface of this trench, and the bottom for about 2 feet from the side walls, also the side walls, were covered with a thin coat of melted asphalt.

Rainy weather in July and August greatly hindered the work, not only by loss of time during the storms but by the time required, after the storms, to render the joints sufficiently dry to receive the asphalt mortar. This was, in large measure, overcome by the use of pulverized quick lime, which absorbed the moisture and imparted sufficient warmth to the joint to enable the mortar to adhere. After the side walls were completed the broken stones and gravel were replaced. New sand was then placed on the entire bed to the depth of $2\frac{1}{2}$ feet. It was found that the stones and gravel had settled about 6 inches.

The different grades of gravel had become mixed to a considerable extent. Sand was found among the broken stones at the bottom.

Whether this intermingling was due to carelessness in the or-

iginal placing of the materials or to the operation of the bed is not known.

The sand placed on the new bed, before described, although screened and washed at the bank, still contained a sufficient quantity of loam to impart turbidity to the filtered water, in greater or less degree, for nearly six months after it was put in service. The new sand placed on the old bed came from the same bank and was screened and washed in the same manner. In order to avoid the difficulty experienced with the new bed the sand was transported from the scow to the bed by means of a hydraulic jet. An ejector was so placed at the dock as to reach the center of the scows and to raise and lower with the tide.

The ejector was supplied with water from the force main at the engine house. A line of 4-inch cast iron pipe extended from the ejector to the top of a tank on the division wall at the center of the old bed. The sand was shoveled into a hopper attached to the ejector on the scow and the water and sand delivered into the tank on the wall. The water, carrying with it the loam and silt, flowed off from the top of the tank and the sand was discharged, through a valve in the bottom, on the bed, perfectly clean, having been thoroughly rinsed in the transfer. The length of the 4-inch pipe, from the ejector to the tank, was 630 feet. Total lift, from scow to top of tank, 30 feet. Diameter of jet 1 inch. Diameter of nozzle 1½ inches. Water pressure at jet about 110 pounds per square inch. Quantity of sand discharged 8 cubic yards per hour. This bed was put in service about the first of October, 1897, and its operation has been most satisfactory from the first.

The sand used in the original construction of the old bed was in two grades, the coarser having been obtained on the bank of the Hudson river at Roa Hook, about 30 miles south of Poughkeepsie. The finer was obtained in New Jersey. In the years of use these two grades have become intermingled somewhat with each other, and with additional sand purchased.

The following table shows approximately the mean diameters of the grains of sand comprising:

First, the lower portion of the old bed, which was removed in 1897.

Second, the upper portion of the old bed, which had been previously removed.

Third, the new sand placed on the old bed in 1897.

Fourth, the sand used in constructing the new bed in 1896.

	1 m. m. and above. Per cent.	.5 m. m. to 1 m. m. Per cent.	.25 m. m. to .5 m. m. Per cent.	.05 m. m to .25 m. m. Per cent.
Old sand removed from old bed in 1897	37	19	41	3
Sand from upper portion of old bed	12	13	53	22
Sand placed on old bed in 1897	25	19	50	6
Sand used in new bed in 1896	24	18	44	14

The old sand removed in 1897 was considerably worn, the grains apparently rounded by the sharp corners having been broken off.

The difference in size between the sand placed on the old bed in 1897 and that used in the new bed in 1896, is due to the washing of the former which removed a considerable portion of the finer sand. The coarser grade of the old sand was very irregular in size; some grains being 6 m. m. or 8 m. m. in diameter, showing that gravel had become mixed with it. The coarser grade of the other sands was quite uniform.

Since December, 1897, both beds have been in operation. Six bacteriological examinations have been made by Dr. Ward of Poughkeepsie showing the following results:

Date.	Source of Water.	Colonies per cubic c. m.	Per cent. removed.
Dec. 23, 1897	Settling basin,	14,160	
"	Effluent, old bed,	166	98.8
"	" new bed,	872	93.
Jan. 6, 1898	Settling basin,	17,850	
"	Effluent, old bed,	132	99.26
"	" new bed,	348	98.02
Jan. 19, 1898	Settling basin,	27,000	
"	Effluent, old bed,	480	98.2
"	" new bed,	900	96.6
Jan. 27, 1898.	Settling basin,	17,850	
"	Effluent, old bed,	52	99.70
"	" new bed,	60	99.66
Feb. 4, 1898	Settling basin,	13,950	
"	Effluent, old bed,	144	98.96
"	" new bed,	88	99.36
Feb. 24, 1898	Settling basin,	19,600	
"	Effluent, old basin,	690	96.47
"	" new basin,	298	98.47

Average old, 98.56 per cent; average new, 97.52 per cent; average all, 98.04 per cent.

The old bed was cleaned on November 13th, and from that date until December 1st, all the water was filtered through it, the river water, meanwhile, being very roily. Since December 1st more water has been drawn from the new bed than from the old. The next cleaning of the old bed was on March 1st, 1898. The new bed has not been cleaned since December 1st, 1897.

The total cost of the original plant, as given in the reports of the department, including land, pumping plant, wells, etc., was $75,694.82. Deducting the cost of land, pumping engine, pumping well and supply and delivery pipes leaves the cost of the bed proper with settling and clear water basins, about $62,000.00.

The cost of the new bed, exclusive of land, was $28,898.70.

For 20 years, from 1877 to 1896 both inclusive, the total volume filtered, exclusive of leakage, was 11,848,600,000 gallons. The total expenditures, in connection with the bed, during that period, was $35,468.37, which gives for the average cost of maintenance and operation, for a period of 20 years, $2.99 per million gallons.

DISCUSSION.

MR. HAZEN. I think that we are all greatly indebted to Mr. Fowler for his paper and the information which it contains. I was fortunate enough to find out several years ago that Mr. Fowler had a remarkable fund of experience and observation upon the subject which he has treated in his paper, and that he was disposed to give others the benefit of his experience. I am particularly glad that he has been able to present some of this material to the Association, and to put on record facts in regard to the first sand filter plant in America, which will be of the greatest value to all interested in the purification of public water supplies.

Mr. Fowler has been operating sand filters for a much longer period than anyone else in America. He has filtered, I think, a larger amount of water than anyone else in America, and the results that he has gotten are certainly very valuable and instructive to us, and the work of the plant as a whole is very suggestive. Mr. Fowler has labored under numerous difficulties. His filtering area has been at times inadequate; the filters were constructed a long time ago, on filled ground, and unequal settlement has resulted in cracks and in a loss of water and also in the flow of the water from one side to the other, which has seriously interfered with the operation of the plant; but in spite of all these difficulties, he has been supplying filtered water for all these years and with admirable results.

He has given you some statistics as to typhoid fever in Poughkeepsie, but to fully appreciate the significance of those statistics one needs to compare them with the corresponding statistics for other cities up and down the river, which have been using the water without filtration, and these other cities have had rates right along several times as high as Poughkeepsie has had, and when there have been epidemics in these other cities Poughkeepsie has remained pretty nearly free from typhoid fever.

I have a tabular statement of the operation of some sand filter plants giving the amount of water filtered for a year, the areas of the filters, the average rates, the area of filter surface cleaned, and the water filtered per acre between scrapings. It is the data one likes to have when one is figuring on the area of filters to be provided, and the cost of operation.

RECENT FILTER STATISTICS.

Place.	Year ending in	Quantity filtered Million gallons.		Area of filters. Acres.	Av'r'ge daily yield. Million gals. per acre.	Filter area cleaned acres. One year.	Million gallons per acre filtered between scrapings.
		For year	Daily Average				
Altona	Mar. 1896	1,730	4.75	3.08	1.55	48.5	
Amsterdam	Dec. 1894	3,720	10.20	10.37	0.98	139.0	27
Ashland	Feb. 1897	398	1.09	0.50	2.18	4.83	83
Berlin	Mar. 1896	13,000	35.60	25.10	1.42		
Bremen	Mar. 1896	1,220	3.34	3.21	1.04	32.5	38
Breslau	Mar. 1896	2,960	8.10	5.12	1.58	40.0	74
Brunswick	Mar. 1896	840	2.30	1.48	1.56	13.3	63
Copenhagen	Dec. 1895	2,330	6.40	2.88	2.22	44.7	52
Dordrech	Dec. 1894	365	1.00	0.56	1.79		
Frankfort on Oder	Dec. 1895	310	0.85	0.37	2.38	2.9	107
Hamburg	Dec. 1895	11,700	32.10	34.00	0.94	275.0	43
Hudson	Dec. 1895	535	1.46	0.74	1.98		
Konigsburg	Mar. 1896	1,085	2.97	2.70	1.10	35.0	31
Lawrence	Dec. 1896	1,101	3.02	2.50	1.20	30.0	37
Liverpool—							
Oswestry	Dec. 1896	4,460	12.30	4.90	2.52	100.0	45
Rivington	Dec. 1896	4,060	11.10	6.02	1.84	58.0	70
Total	Dec. 1896	8,520	23.40	10.92	2.14	158.0	54
London (rivers only)	Dec. 1896	72,482	198.00	123.75	1.60		
Lubeck	Mar. 1896	1,600	4.38	1.40	3.13	24.4	66
Magdeburg	Mar. 1896	1,950	5.35	3.76	1.42	65.0	30
Mt. Vernon	Dec. 1896	608	1.66	1.10	1.51	9.2	66
Posen	Mar. 1896	346	0.94	0.70	1.35	10.4	33
Poughkeepsie	Dec. 1896	664	1.82	0.68	2.68	9.0	73
Stettin	Mar. 1896	1.030	2.83	2.26	1.25	15.5	66
Stockholm	Dec. 1895	2,375	6 50	2.78	2.33	70.0	34
Stuttgart	Mar. 1896	1,220	3.34	1.66	2.04	17.7	69
Zurich	Dec. 1896	2,360	6.45	1.66	3.88	30.0	79

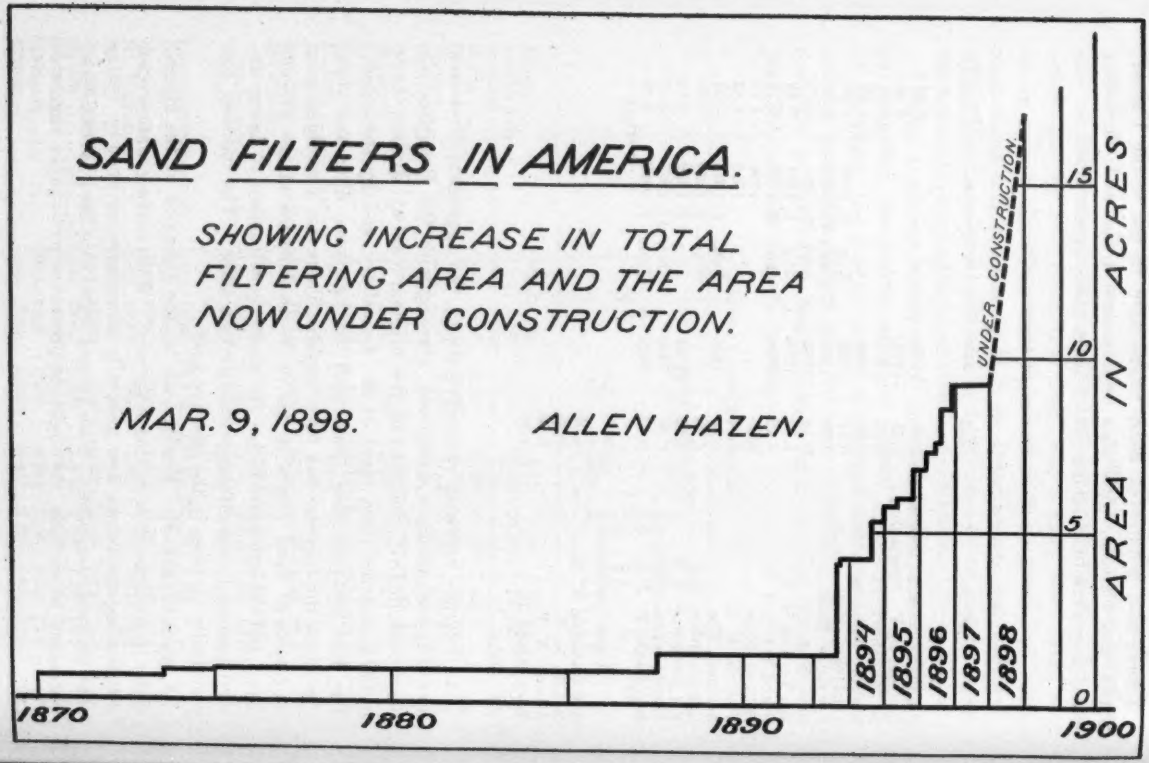
I have also a table of sand filters now in use in the United States and Canada, with their approximate areas, and the dates when they were built, and a list of filters under construction.

SAND FILTERS IN AMERICA.

Place.	Area, Acres.	Built.	In Operation.	Total Area to Date.
Poughkeepsie N.Y., (original)	0.68	1872		0.68
Hudson, N, Y., (original)	0.21	1874		0.89
St. Johnsbury, Vt	0.05	1875(?)		0.94
Hudson, addition	0.53	1888		1.47
Nantucket, Mass	0.11	1892	Aug. 8, 1893	1.58
Lawrence, Mass	2.50	1892-3	Sept. 20, 1893	4.08
Ilion, N. Y	0.14	1893	Sept. 30, 1893	4.22
Mt. Vernon, N. Y	1.10	1894	Aug. 1, 1894	5.32
Grand Forks, N. D	0.42	1894	Jan. 4, 1895	5.74
Milford, Mass	0.25		1895	5.99
Victoria, B. C	0.83		1895	6.82
Ashland, Wis	0.50	1895	Feb. 5, 1896	7.32
Lambertsville, N. J	0.28		May 4, 1896	7.60
Far Rockaway, N. Y	0.92	1896	July 1, 1896	8.52
Poughkeepsie, addition	0.68	1896	Dec. 17, 1896	9.20
Red Bank, N. J	0.03	1897	June 5, 1897	9.23
Under Construction.				
Somersworth, N. H	0.50			
Nyack, N. Y	0.39			
Albany, N. Y	5.70			
Rock Island, Ill	1.20			

A diagram herewith presented shows the aggregate filter area up to the various dates mentioned, starting with the Poughkeepsie plant back in 1872, followed by the original plant at Hudson, built in 1874, and the little plant at St. Johnsbury, and by the others. The first great increase came with the Lawrence filter and since that time the increase has been rapid. There are something over nine acres of sand filters in use in North America at the present time, and enough more filters are under construction to bring the total area up to something over seventeen acres. The increase has practically all been in the last five years.

I want to ask Mr. Fowler, as to the behavior of the filtered water in his open distributing reservoir. With surface waters open distributing reservoirs are generally considered as good or better than covered reservoirs. With ground water supplies it is considered necessary to exclude the light, to prevent objectionable vegetable


SAND FILTERS IN AMERICA.
SHOWING INCREASE IN TOTAL FILTERING AREA AND THE AREA NOW UNDER CONSTRUCTION.
MAR. 9, 1898.
ALLEN HAZEN.
AREA IN ACRES
UNDER CONSTRUCTION
15
10
5
0
1894
1895
1896
1897
1898
1870
1880
1890
1900

growths. Now filtered river water in its characteristics comes between ground water and surface water, and it has been pretty commonly thought in some places that it was necessary to store filtered water in covered reservoirs. I would like to have Mr. Fowler state, if he will, whether he has observed any objectionable tastes or odors from the growth of organisms in his distributing reservoirs; and, if there is anyone here from Lawrence, who knows about the Lawrence conditions I wish we could have some information in regard to Lawrence in that connection, and, also, as to whether there is any difference between the new high service reservoir at Lawrence, which is covered, and the old reservoir, which is open?

MR. CLARK. In regard to that matter I will say that at Lawrence they have had in the open reservoir a growth, one or two summers since the filter was put in, of fresh water sponge, which has caused a slight taste and odor in the water, but the sponge grew there before the water was filtered. That is the only thing we have noticed at all. In the stand-pipe the past year there has, of course, been no growth, so far as we could observe, and there was only a very slight growth in the reservoir last summer, nothing that anybody noticed except in a few houses.

There is one thing Mr. Fowler spoke of I should like to mention, and that is the growth of this algæ on the surface of the filter. His filter, I understand, is a continuous filter, and is covered with water except at times of scraping. At the experiment station we have had in operation for some years both continuous and intermittent filters. They were both uncovered until the fall of 1895. During the summer of each year that we operated these filters before covering, there was a growth, generally in September, I think, of this spirogyra, on the surface of the uncovered continuous filter, but it did not grow on the surface of the intermittent filter; neither has it occurred to any extent at the Lawrence city filter. There has been a slight growth in patches here and there from time to time, but nothing that has caused any trouble. Since the fall of 1895 the experimental filters at the station have been covered, that is, we have a board covering over them about three feet above their surface, and there has been no growth of this spirogyra on the filters since that time.

Mr. Fowler also says that the filtration of the river water at Poughkeepsie has not affected the color to any extent. With our

filters at Lawrence we remove about from 30 to 50 per cent of the color at different seasons of the year. In the fall sometimes, when the river water is high and very highly colored with the washings from swamps or woodlands up the river, we do not remove more than 25 to 30 per cent; in other portions of the year we remove 50 per cent. It is different with the Lawrence city filter, of course. As you know, that is built upon a mud bottom, and we have coming into it ground water containing considerable iron, which colors the entire water from the filter to a certain extent. That is to say, the ground water with the iron gets in with the filtered water, and causes an increase of color over what the real filtered water has, but as a general thing, as an average for the year, we have removed 30 per cent of the color from the river water, even after the addition of this iron water.

Now, in regard to the death rate at Lawrence before and since filtration, I presume it is pretty familiar to most of you that for a number of years before we had the filter, typhoid fever was epidemic in Lawrence each year, and we had death rates ranging from 10 to 12 or 13, I believe, per 10,000 inhabitants. The year the filter was built, 1893—it was put in operation the 20th of September—the death rate was a little over 8 per 10,000; in 1894 it was 5 per 10,000; in 1895 it was 3.07 per 10,000; in 1896 1.86 per 10,000; and in 1897 1.62 per 10,000. The death rate from typhoid has certainly gone down. I may say that a little while ago I heard two doctors and one of the undertakers in the city complaining bitterly of dull times in Lawrence. They stated that their occupation was practically gone in the months of the year when they were formerly very busy. [Laughter.] I was talking with a stablekeeper the other day also who has in his stable the wagons and horses of two undertakers, and he said that they had been in about every day for the past two weeks, saying that nobody was dying, and they didn't know whether they should be able to pay their bills; in fact, I think he said they hadn't paid their bills. [Laughter.]

I don't think I have anything further to say in regard to filtered water, except that the death rate and the disease records of the city show that apparently other diseases beside typhoid fever have been lessened. We sometimes have complaints of the appearance of the water and the taste of the water as it is delivered to the consumer. Generally those complaints are from people who live

near the ends of pipes, dead ends, so-called; and there is an accumulation of iron there and stagnant water. But the people who complain the most bitterly, and whose cases we look up by going to their houses to take samples, always say when we get there that the water has no odor that day. [Applause.]

MR. FOWLER. Mr. President, just briefly to answer the questions asked, I will say, first, with reference to odor in our reservoir water, that since I have been in charge there has been no difficulty experienced whatever. I am told that previous to that time there was an occasional odor, that is, this fishy odor which is very common, and it has occurred once or twice since in the dead ends, as was referred to by Mr. Clark; but during my administration no trouble has occurred in the reservoir.

With reference to our filter being continuous, it is continuous in that most of the time the basin is covered, particularly in the winter; but our pumping is not continuous. We pump generally 3½ to 4 days in the week, and the filter works during that time, though we aim to keep the water on the filter. But in the summer time we have sometimes allowed the water to go off the filter and drain dry, hoping that the rays of the sun would kill the alga growth, but it does not do so with us. As soon as we turn the water on it begins to develop again.

With reference to typhoid fever, you notice two instances in my table of very high rates. Now, it is a fact that a number of the cases of typhoid fever in our city originate outside, because we have quite a large number of transient students in our college, and typhoid fever occurs frequently among those, and perhaps the variation in the rate may be due to some such fact as that.

MR. CLARK. There is one thing I should like to add to what I said before, and that is that we still have canal water piped into some of the mills, and a number of the deaths that go to make this record of typhoid fever are of people who have acknowledged drinking the canal water. We have had two deaths from typhoid fever thus far this year, one in January and one in February, and in one case the man acknowledged that he had been in the habit of drinking canal water at the mill.

MR. HASKELL. I would like to ask Mr. Clark if it is not probable that there is less danger from typhoid fever from the use of the filtered water in Lawrence, water taken from the Merrimac and

filtered in their filters, than there would be from an ordinary surface water supply unfiltered?

MR. CLARK. I don't know just what an ordinary surface water supply is. You can have a surface water supply that is perfectly pure, I suppose, from a pond that is not contaminated at all. There are a number of surface supplies in Massachusetts that are contaminated to a certain extent and used without filtration, that is, they are liable to contamination, and I think by using such a water there is more liability of typhoid fever occurring, certainly, than with a filtered water.

Mr. Fowler made some statements in regard to the bacteriological efficiency of the filter. Our filter at Lawrence does better work than his, better bacteriological work. We make analyses of its effluent every day for the largest portion of the year, and I can say that for the past three months, while the average number of bacteria in the river water has been towards 6,000 or 7,000 bacteria per centimetre, I don't think there has been but one or two days when the numbers in the filtered water have averaged over 50, generally down to 25 or 30. We are making a good many additional tests this year. We test the filtered water every day for the presence of coli, the characteristic sewage bacteria; and, while I am not ready to make any statements in regard to those results, I will say that they certainly show an efficiency in that respect that can hardly be shown by percentages. There is a practical elimination of sewage bacteria. And if we do find any, we have generally found a cause for it. There has been something going on in the pumping station, the testing of the pump, and the water allowed to flow back over the floor of the station into the pump well, or something of that sort.

MR. HASKELL. Will Mr. Fowler explain the algæ growth on the bed of this filter?

MR. FOWLER. The algæ growth to which I referred is simply the growth of the plant. It does not affect the water in any way I am aware of, either by odor or taste. It simply grows on the top of the sand and stops filtration, that is the only way it affects us; and the only way we can get rid of it is to stop filtering, drain the bed, and take it off with shovels. It develops on the bed, it is not in the water and taken out on the bed, but it grows on the sand. Perhaps the germs may be in the water, but the algæ, the plant itself, grows on the sand. It will start in a little bit of a speck and grow in a

circle like a dollar until the whole bed is covered as with a blanket.

MR. THOMAS. I would like to inquire of Mr. Fowler if the filtration of the water has increased the hardness to any appreciable extent?

MR. FOWLER. So far as chemical examinations have been made there is no difference, I believe, between the hardness of the unfiltered and the hardness of the filtered water. The total solids are reduced, of course, but I think there is little if any difference in the hardness.

THE PRESIDENT. Professor Sedgwick, will you say something on this subject?

PROF. SEDGWICK. Mr. President, and gentlemen of the Association, I have suggested to your secretary that this paper is so valuable and so full of material that it ought to be thoroughly discussed by all the members present, who ought to embrace this as a rare opportunity; and that to that end I should be very glad to defer what remarks I was going to make in the form of an informal talk to another occasion. And with that in view, I should like to say one or two things about Mr. Fowler's paper.

This is really a rare occasion. Here is the one man in the United States who has had a long experience with sand filtration of a highly polluted water, in a northern winter, with the ordinary American community to deal with and get his money from—a longer experience, as Mr. Hazen very truly says, than any other man in the United States. He has used a filter built by the eminent Mr. Kirkwood, and one which, so far as I can judge, has on the whole efficiently protected the citizens of Poughkeepsie from typhoid fever.

One or two questions which have been asked suggest the idea that should always be kept in mind, viz:—that typhoid fever does not come entirely from water, so that when the typhoid rate is reduced to a low point, as it has been in Poughkeepsie, and as it has been in Lawrence, we may say that there is no more typhoid fever in a city of that kind with these low figures than there is in many cities having absolutely unobjectionable water supplies, derived from very pure sources. It is necessary to make this statment very squarely and flat-footedly, because one or two engineers in particular have from time to time insisted that as long as there was any typhoid fever in a city, the filter, or water supply, whatever it might be, must be at fault, and that the only remedy is to use distilled water.

Well, that is absolutely false. The right test in these cases is to see whether the amount of typhoid fever remaining after the introduction of the new system, whatever it may be, is any greater than would be found in a similar city supplied with water drawn from perfectly unobjectionable sources.

Now, in the case of the Merrimac river water it is easy to get at that, because there are cities above and below Lawrence that have remarkably good water supplies. They are of the same climatic situation, they have the same late winters and early falls; and they are under the same Divine Providence, which some people still think is responsible for typhoid fever; they are occupied in the same or similar industries, they have just about the same surroundings, the people in the different cities are of similar classes; and with the rate in such cities the rate, for instance in Lawrence, should be compared, and not with the figure zero. There is not a city in the country that hasn't some typhoid fever, and there are many cities in the country that have water supplies which cannot be conceived of as polluted.

It seems to me that the results given here, especially these results in more recent years, when Mr. Fowler has had the advantage of modern sanitary science, are figures which are highly noteworthy; and even the earlier figures, when the filter was run without the modern knowledge of filtration, are also very helpful. The paper is not only full of practical value, but as I look at it has an historic importance; and I for one, sir, am very glad you have consented to read it before this Association, in order that it may go into our JOURNAL and be accessible to all the members of the New England Water Works Association; because we, who are members, believe that this Association does not yield the first place to any such association in the world. We are glad to get papers of this kind, and we appreciate them when we do get them. They are genuine contributions to sanitary science, as well as to the science of water works engineering and management.

I should say that the city of Poughkeepsie had been fortunate in its superintendent. And, while that may seem an empty compliment, let me assure you that it is not so, for there is in all these water supplies the human element. Mr. Fowler discovered it when he found his engineers letting the water run over into the waste-pipe to avoid cleaning the filters. There will always be a human element

in the management of everything. Locomotive engineers will once in a while disregard signals and have collisions, rear-end collisions and the like. Admirals, like the English Admiral on the warship Victoria, will once in a while give directions to turn when there is not room to turn, with the result that they and their ships go to the bottom. There is a human element in all these things, and that water supply is to be esteemed fortunate which has for its administrative officer a man who is persevering, watchful, intelligent and faithful; and such, I believe, most of the water works in New England do have, and all over the country, for that matter. They have to have them, or the people will come to grief.

With regard to the question raised by Mr. Haskell, I had come with considerable talk bottled up on that subject. I am proud that more than a year ago I was able to read a paper before this Association, and that it is printed in our reports, on the Protection of Surface Waters from Pollution. It was the first thing of the kind, so far as I know, that has gone into print, but it is not going to be the last. There have been very serious epidemics in England, particularly within the last six or eight months, three above all others—Maidstone, Lynn, King's Lynn, I believe the full name of it is, and Horsley; where in at least two, and perhaps in all of the cases, a surface water, which had previously been supposed to be pretty pure, that is it was by some, although it had been condemned by others has been the source of very serious damage indeed, and I had come prepared to speak on that subject. But I came with this distinct understanding—it was possible Mr. Fowler might not turn up, and I offered to come only as a stop-gap. I do not propose, therefore, to distract attention, if I could distract it, which I very much doubt, and which I certainly do not want to do, from this very valuable paper. I think an afternoon where we have had reported an experience of seventeen years from a man like Mr. Fowler, on a subject which is certainly the coming subject of water supply all over the world, is an afternoon which has been amply filled, and I do not propose to bring in any other subject at this time.

I do wish to say, however, that Mr. Haskell's question is very well raised. There is no doubt whatever that a surface water which has some little brook sneaking into it, over which privies are hanging, and into which typhoid dejecta are dropping, is a more serious menace to the people using that water than is any

rather badly regulated filter. I would rather take my chances with sewage polluted water filtered intelligently and well, than with a surface water I knew nothing about. And if the time should come when I could give you some extended talk on that subject in amplification of my paper of a year or more ago, I should be very glad to do it, because we are learning every day how serious, as population increases, are the dangers from surface waters not properly watched. It is the watching of the watershed that is our salvation in these cases, and the cleaning of it up. These recent epidemics have set all England in an uproar. I am not exaggerating it one bit. The people are more stirred up in regard to water supply there than they have been for probably twenty-five years.

I happened to be over there this summer, but, unfortunately, the Maidstone epidemic did not occur until just after I reached home. I should have been very glad to have been there and brought you a report of what I could have found on the spot. Since then there have been that great epidemic and two more. It really seems today as though American sanitation in water works affairs was far superior to the English system and practice. The fact is England has been lying on her oars in this matter while America has been forging ahead. And it is a matter of national congratulation, I think, that our water supplies are, as I believe they really are on the whole, our surface water supplies, in better repair and in better condition today, than the average English surface water supplies, for several reasons, which I will not go into now. I wish personally to thank Mr. Fowler for the trouble and time he has taken to prepare and to put this paper on record. It is a matter of congratulation that we have his experiences, and I hope he will come often and give us further chapters from his experience.

MR. HASKELL. There is one other point I wanted to develop to a certain extent in relation to Mr. Fowler's paper, and it is something that ought to seem perfectly surprising, and that is the cost of operating a sand filter. When we think of the vast amount of money individuals are spending in trying to operate some of their filters—I know where they are changing the materials in their filters every three or four weeks, and purchasing quartz in large quantities, —here we find a man who has operated a filter for a long period of years, who has succeeded in getting 97 per cent bacterial efficiency from the use of his filter for a long period, whenever there have

been examinations made, and he has done it all at an expense of less than $3 per million gallons.

Now you all know that the bacteria are the dangerous things in the water. The disagreeable things may not be so fully eliminated, but the dangerous ones have been eliminated by Mr. Fowler to the extent of 97 per cent. And there is hardly any city that could not afford to add $3 a million gallons to the cost of its water, when very likely it costs $85 or $90 a million gallons for maintenance and operation. Calling it $85, it wouldn't add but a small per cent to filter the water. And when we know how easy it is for a camp of gypsies or somebody else to catch around on the edge of a water supply, and stop there, and perhaps send typhoid fever down into the service, or for some of these Italian camps to be located around on a water supply, and that one or two cases of typhoid fever there can produce an epidemic in a city, it does seem as though the attention of everyone ought to be fully brought to the importance of these filters, and also to the cheapness with which they can be supplied and operated.

PROF. SEDGWICK. There is one point which Mr. Haskell's remarks remind me of, and which I think ought to be borne in mind when we speak of the efficiency of filtration. We speak, Mr. Fowler has spoken, and Mr. Clark has, and we all do, of the reduction of bacteria as 97, 98 or 99 per cent, and so on. Now what does that mean? It means that there are so many bacteria to a cubic centimetre in the water before filtration, and so many after filtration, and we speak of that as a reduction of so many, or so much per cent. But it ought always to be borne in mind that the real reduction of applied bacteria may be very much greater than that, and for this reason: It often happens that a natural filter is a place where bacteria, fed as they are by a constantly passing stream of water, may somewhat multiply. Those, of course, will only be the harmless water bacteria, at least that is a fair assumption. And I know it has been tried at Lawrence to find a term which should express the thing a little more exactly than to say there was a reduction of 97 or 98 per cent. It is a difficult thing to do, because if you try it, you will find that any expression which really states all the facts is rather long and cumbrous.

There are a great many house filters, for example, which actually give out more bacteria than they take in, but they are perfectly

harmless bacteria, so far as we can judge, from the fact that the people drinking the water seem to be in excellent health and to have no trouble from them at all. But if there are 1 or 2 per cent of bacteria still found in the effluent water, I do not think there is any doubt at all that a certain proportion of those have got to be charged up to the natural development of the bacteria in a filter to which food is coming all the time. It is a place where bacteria reside, and if they reside there they will multiply more or less, so that the real efficiency is higher than the apparent efficiency in all these cases.

And then you will remember that you are dealing with a germ like the typhoid germ, which is all covered over, as it were, with whiskers, it has cilia all over it, and to pass that through sand is very much like trying to pass, for example, a hair brush which has bristles not merely on one side, but all around it. That is a kind of thing that tangles up there far more than the bacteria which are not covered with these lashes, or, as I have roughly called them, whiskers, which cause entanglement. And I haven't the slightest doubt in the world that the real efficiency of these sand filters is far greater than the apparent efficiency. So when it comes up to 99 per cent., for instance, the figure very likely is 100 per cent. of the bacteria actually put on, and especially of bacteria like the typhoid germ. Unfortunately it is not easy to state that.

Everybody assumes that if we put on 100 bacteria, 99 of those bacteria stay there and one of them slips through. Well, sometimes undoubtedly they do slip through, and sometimes undoubtedly they do not slip through, but those which come out below are really those which were raised, perhaps, on the underdrain or in some such place as that. So that the real efficiency of these filters on the whole, in my judgment, is a good deal higher than the apparent efficiency, and for good reasons.

MR. HASKELL. There is one matter, which is very important, connected with the construction of these filters, about which I would like to get some information from Mr. Clark or Prof. Sedgwick. There was a time when we did not consider there could be more than 750,000 gallons of water per acre properly filtered with a good bacterial efficiency. Now, as I read the reports of the State Board of Health, I find that they are increasing in their bacterial efficiency. I really think they have got nearly to ten million gallons per acre

per 24 hours, and I think they have maintained for the year continuous work as good as 99.70 to 99.73 per cent. Now that means a good deal in the construction of a filter, and if we can get that fine work through a continuous filter, I should like to know it, and I didn't know but Mr. Clark or Prof. Sedgwick could tell us.

MR. CLARK. We have never operated any filters at so high a rate as 10,000,000 gallons except for a few weeks at a time, and then we have got apparently very good results. But, taking the filters which we have been operating for a number of years at the experiment station, the average rate of filtration has been rather less than 4,000,000, three million six or seven hundred thousand, with our largest and best sand filters. I myself believe that with careful handling of a small plant, with intelligent direction, you can perhaps filter a water, something nearly as badly polluted as the Merrimac river water, at a rate approximating 4,000,000 gallons per acre daily, but I think that a safe rate is 3,000,000 gallons, with the care which the filters on a large scale would generally receive. I, certainly, if I was building filters, or recommending filters for any municipality, should not advise that the rate be over 3,000,000 gallons per acre daily. I think that the economy in running a filter at the rate of 3,000,000 gallons is greater than at the rate of 5,000,000; that is, I think there will be more scraping, more washing of sand and changing of sand at the rate of 5,000,000 than at the rate of 3,000,000, that is, a greater cost per million gallons of water filtered. This whole question depends, however, upon the character of the water to be filtered.

MR. FOWLER. Mr. President, may I be allowed one word with reference to that point. I think that in examining the paper, which the gentlemen have been so kind as to speak so favorably of here, one thing will be prominent, and that is that a larger area is necessary in constructing filters than just the area sufficient to do good work when everything is in perfect order. Therefore, if 3,000,000 gallons, which I fully agree with Mr. Clark ought not to be exceeded, is the quantity wanted per day, we should have a certain amount in excess, in order that we may always have our area for 3,000,000 gallons per day in perfect order. I find that the great trouble with my work. I worked for 16 years with one filter

of the size I gave you, two-thirds of an acre in extent. Now we have just built a new filter equal in area to that, giving us one and one-third acres. If we were to operate an uncovered filter, I should not consider the plant perfect for use until we had one more filter of one-third of an acre in area, that is in order that it might be in perfect order at all times. Of course that is something I don't expect to get, probably, during my administration; but I shall not say that our plant is perfect for our city until we have a little more surface, so I may always have the two I now have in perfect order.

MR. HASKELL. It seems to me that perhaps Mr. Clark is a little too modest about telling us of the final results they have secured up there in Lawrence in some of their experiments. My memory is not as good as it was once, but I have read the reports each year, and if I remember correctly, filter A, I forget the number now, it may be 58, has been operated for 11 years. They operated it in different ways and they did very good work with it, and they finally thought they would construct a filter as near as they could under the conditions which would apply to an ordinary water supply, and they have operated that now, I should think, about six years. It was run at the rate of over 4,000,000 per day of 24 hours, and practically run continuously for the term of four years. And I think by the report for 1896, it appears that for the three years run at that rapid rate continuously the percentages were 99.70, 99.73 and 99.50. Now it did do nearly as good work as that, didn't it, Mr. Clark, although you wouldn't fully recommend it, and it did it under conditions copying as near as possible a practical filter!

MR. CLARK. I said, Mr. President, that I thought small filters, with careful watching hour by hour, with intelligent management, could be operated at these high rates. When I said "small filters," I meant filters such as we are running at the Lawrence experiment station. I have no doubt however that a filter with a surface area of an acre or half an acre, receiving water like the Merrimac river water, can be operated, if extreme care is given to it, at a rate approximating 4,000,000 gallons per acre daily; but I believe a safer rate is a little lower than that, and I do not think, with my

present knowledge of the subject and my present experience in operating filters, I should ever advise a rate as high as 4,000,000 gallons, with such water as the Merrimac river water. Still we have got for the past four years extremely good results with an experimental filter, 17 feet in diameter, running at a rate approximating four millions; I don't think the average has been four millions. I think it has been about 3,600,000 for the four years.

MR. HAZEN. I have come to the conclusion that different waters can be filtered at different rates, and that it is perfectly possible to filter some waters with high bacterial efficiency, at rates at least twice as high as can be successfully used with other waters. I am not going to tell you all the conditions which influence or control the possible rate of filtration, principally because I do not fully understand them myself, although we are learning something about them. In regard to the efficiency that is secured by the operation of filters, there is the efficiency which is gotten when the filter is in perfect condition, and there is the efficiency which is gotten when the filter is in a defective condition. And I think that the lower bacterial efficiencies resulting from defective conditions have been a good deal more common than has been generally supposed.

One of the commonest defects of a filter plant is for the unfiltered water in some way or other to get around the sand into the under drains. Mr. Fowler told you how it went through his ventilator pipes. Filters have been built without any ventilator pipes, and they work just as well without them, and this danger is avoided. Sometimes the sand will cake a little, and it will draw away from the wall, and the unfiltered water will run down the wall. We have corrected that by putting some little ledges or jogs in the wall, and the sand makes a better joint on a horizontal surface than on a vertical surface. That was a good idea as far as it went, but even with those jogs the masonry may sometimes crack, and the water leak into a crack above the sand line and come out of a crack below the sand line. Now we are building filters keeping the gravel back from the outside walls all the way around. It perhaps reduces the area of the filter a little theoretically, but if the water comes down the wall in some way, it has to pass along the bottom through the sand before it gets into the underdrains. We

keep finding out such things as that. Mr. Haskell asked me today if we were ready to build a perfect filter. I told him no, we didn't expect to build a perfect filter for a long time yet, but we are building as good filters as we can, and are learning more about how to do it all the time, and are building filters which will do very good work, even if they are not perfect.

LOSS OF WATER FROM PIPES.

BY F. H. CRANDALL, SUPT., BURLINGTON, VT.

[*Read February 9, 1898.*]

The determination of the loss of water from any considerable system of underground piping is at best problematical and does not admit of definite unquestionable solution, but in the case which I will endeavor to present for your consideration, some of the difficulties ordinarily encountered have been eliminated.

Systems, even of such small extent as that to which your attention is invited, on which for months at a time there is no occasion to open public fire hydrants, on which there are no large manufacturing concerns using water for fire purposes and on which all ordinary legitimate use is metered, are not numerous. On the Burlington High Service, however, it has recently come about that these conditions obtain.

By far the larger portion of the pumpage on this service is accomplished by a motor, an auxiliary steam plant being used only when for one reason or another it becomes necessary. The works were built in 1880 and 1881 and now supply the University buildings, the State Agricultural Experiment Station and farm buildings, two Roman Catholic schools, one hospital and five summer residences with innumerable fixtures, beside 45 dwellings, nearly all of which are supplied with modern conveniences in plumbing. Some of the mains were laid in rock cut and some are for the greater portion of the year, below the ground water level. No more than usual care was taken in the laying, and no more than the usual amount of trouble has been experienced from them since. The work was not contracted.

The average pressure on fixtures is about 35 pounds, and on the majority of the services (on those of all the larger consumers), a main tank with supply controlled by a ball-cock covers nearly all the fixtures.

The service comprises an iron tank of 2,260 cubic feet capacity, 9,671 feet of cast iron mains from 4 to 8 inches in diameter, and about 1,560 feet of 4-inch cement mains, with six public fire hydrants, one 4-inch and two 2-inch services supposed to be used for fire purposes only, 62 metered taps through which water is used for domestic purposes, one 3-inch metered elevator service, one 2-inch overflow, metered, and one 1¼-inch metered service used to supply power for operating valves of the motor.

The meters in use on the service are of the Crown, Nash, Empire, Bee, Lambert, Union Rotary, Union Piston, Disc and Trident make. Each of the meters used on the service at the time of setting, registered on full size ⅛-inch and 1-16-inch streams not more than two per cent fast nor more than 3 per cent slow. By sizes, the meters in use are one 3-inch, two 2-inch, two 1½-inch, seven 1-inch, seven ¾-inch, forty-one ½-inch, and five ⅜-inch.

As the discharge of the motor is conveyed to the tank by way of the distribution system, and thus far conditions have not been favorable for accurate measurement, the losses in the pump can be got at only by estimation.

The plunger in the pump end of the motor, which works against about 41 pounds static, 43 dynamic head, is 4 and 7-16-inches in diameter, and is provided with a double cup leather packing, which has frequently been found, when the plunger is not in motion, to be absolutely tight at different points of the stroke. In motion a small leakage is developed. There is also leakage of the ports, and though at different times when the motor has been opened for repairs, the high service pressure being applied on the pump side, there has been no leakage noted through the leather packed stuffing-box between pump and motor, in practice there must be some leakage at this point.

The motor and pump are set up tandem, and at the other end of the rod, to which is attached the pump plunger, another and a larger plunger in the motor barrel is attached. These plungers and their rod passing through the aforementioned stuffing-box in the head common to both motor and pump have, when at work, more or less rotative motion.

The leakage through this stuffing-box, between the pump and motor, cannot conveniently be separated from that through two 10-inch gates under the low service pressure (about five pounds). All

three together have frequently been found to amount to less than one per cent, and in the different tests made it has developed that reliable information is not to be obtained from the measurement alternately for equal intervals of the total leakage and that from the gates alone, as the leakage of the two gates alone was often in excess of that of gates and stuffiing-box taken together.

The suction and discharge ports of the motor pump are each 12 in number, about three inches in diameter and capable of one-half inch lift. The motor runs at from 4 to 32 strokes per minute and will not run many minutes at the maximum speed. The average is about sixteen strokes per minute.

Beside the losses common to all pumps a further source of error in the counter measurement in this case is the shortening of the stroke on small streams such as obtains in some meters, and which in this case at times reaches three per cent of the stroke. It is not, however, expected that in practice the motor will be required to run for any considerable length of time on a very small flow.

In the endeavor to obtain some idea of the tightness of the pump plunger when in motion, motion was imparted to it when under pressure by means of a rod threaded for the full length of the stroke and operated through a threaded hole in a bar bolted across the opening made by the removal of the cylinder head.

The motor is supplied with a regular pump counter and the record of its strokes is probably as accurate as is generally obtained. The pumpage of the steam plant was, perhaps, not as accurately determined. It was taken to be the increase in depth of water in the tank during the time of its operation, which usually took place at times when there was little or no consumption.

The records for the two periods into which the total period may be divided, during one of which the steam pump was used and the average daily consumption was about 4,770 cubic feet and during the other of which the steam pump was not used and the average daily consumption was about 3,552 cubic feet, do not differ materially in the percentages not measured.

In taking statements of the meters recording the consumption, about two hours are consumed, and the counter of the motor is read during that time. For very short periods the pumpage during the time of taking statements and a slight variation of depth in the tank tending in the same direction would have a noticeable effect,

but for long periods any error which could arise from these causes is so slight as to be neglectable.

In determining the correction to be applied to the counter record for losses on the pump, taking the leakage of the ports at the mean noted during several tests, made under static pressure, that of the plunger at the mean noted while moving with considerable less than its usual velocity against the static pressure and that of the stuffing-box at an arbitrarily chosen amount equal to one-half that of the plunger, we have an aggregate loss, under the conditions noted of about one per cent, and for purposes of estimation we will assume the losses under working conditions at five per cent.

Records are at present obtainable of the pumpage and consumption on this service for a period of eleven months, during which every legitimate use of water, except such as made by the water department, was supplied through meters. During the period under consideration there was no occasion for the use of water for fire purposes on the high service.

During the first eight months for which records are kept, the steam plant was called upon but five times. The total amount of water handled was 1,144,907 cubic feet. 1,088,563 cubic feet, or about 95 per cent by the motor, (as per indicator), and 56,344 cubic feet, about 5 per cent by the steam plant. (Determined as before stated). Of this indicated pumpage,

729,282	cubic	feet,	about	64	per	cent,	was metered to consumers.
193,285	"	"	17	"	"	"	" motor.
39,040	"	"	3	"	"	"	" overflow.
27,630	"	"	2	"	"	estimated to consumers.	
57,245	"	"	5	"	"	the estimated loss in pump.	
98,425	"	"	9	"	not accounted for.		

During the last three months for which records are obtainable, the steam plant was not called upon at all. The total amount of water handled was (as per indicator) 319,734 cubic feet. Of this indicated pumpage,

230,375	cubic	feet,	about	72	per	cent,	was metered to consumers.
40,360	"	"	13	"	"	"	" motor.
1,680	"	"	5	"	"	"	" overflow.
2,024	"	"	5	"	"	estimated to consumers.	
15,986	"	"	5	"	"	"	loss in pump.
29,309	"	"	9	"	not accounted for.		

During the entire period for which records are available, eleven months ending February 1st, 1898, the total amount of water handled was 1,464,641 cubic feet—1,408,297 cubic feet, or about 96 per cent by the motor (as per indicator) and 56,344 cubic feet, about 4 per cent by the steam plant. (Determined as before stated). Of this indicated pumpage,

959,657	cubic feet,	about	65	per cent	was metered	to	consumers.
233,645	"	"	16	"	"	"	" motor.
40,720	"	"	3	"	"	"	" overflow.
29,654	"	"	2	"	" estimated	to	consumers.
73,232	"	"	5	"	" the estimated	loss	in pump.
127,733	"	"	9	"	not accounted	for.	

DISCUSSION.

THE PRESIDENT. Mr. Brackett, I think you have had something to say heretofore on loss of water from leakage and other causes.

MR. BRACKETT. I think that might perhaps be a good reason why I should not have anything to say now, and I do not know that I have anything new to say on this subject. It has been one to which I have given considerable attention, but not for some two or three years. I should think that a loss of nine per cent, which Mr. Crandall reports, was somewhat less than has been observed in other cases. Of course in his case he had a comparatively short pipe system, and with a larger and possibly older system, I think the loss would be greater. In some cases I have known of, where almost all the water that was pumped was metered, the loss has been as high as thirty per cent. The difference is supposed to be due to leaky mains. Perhaps that statement had better be qualified by saying leakage from mains and loss from the meters. Of course we all know that meters that have been in service long enough will have a certain loss, so a portion of that thirty per cent should be charged to the loss through the meters.

MR. WHITNEY. I should like to ask Mr. Crandall how long those meters had been in use at the time he made the experiments?

MR. CRANDALL. Some of the meters had been in use ten or twelve years, but just prior to the commencement of the test every meter was overhauled and tested, and when the test began, they had within a month of that time, been found to register within the per cent named.

MR. RICHARDS. I would like to ask Mr. Crandall if the pump plunger always completed its stroke, if it made the entire stroke every time?

MR. CRANDALL. I called attention to the fact that in the motor, as in some makes of meters, on small streams or slow velocities, there is a shortage in the stroke, which, in this case, I thought amounted to fully three per cent of the stroke, but that in practice we do not expect our motor runs much of the time with so short a stroke as that. I allowed three per cent as the loss on that one account, and the other two per cent was for ordinary losses through valves and leakage past the plunger.

MR. RICHARDS. I think there is no doubt but that there is a very considerable leakage in mains very often, not large in any one place, but very small in a great many places, and that the sum total amounts to a big figure. It often happens, as we all know, that there may be a big leakage in one place which we do not discover, yet I think the leakage comes mainly from very small joint leaks in a great many places.

THE PRESIDENT. Mr. Kieran, can you give us some information in regard to loss of water in Fall River?

MR. KIERAN. Mr. President and gentlemen: I am sorry to say that our loss is much greater than Mr. Crandall's as far as we can get at it. During the past year we have been making some investigations, and we found that the loss was 40 per cent, that is taking the whole pumpage, and taking the whole supply for the town. We have one and not two systems (as I understand Mr. Crandall his experiment has been made on the high service) and it is most all metered. The greater part of our consumers are metered, and over 90 per cent of our revenue comes from the metered service. But our city is supplied for all public institutions and places free, and they use the water pretty freely too. This year I hope we shall be able to stop a great deal of it, for the reason that we have been metering the public places, schools and stables and the City Hall, watering troughs, parks, etc. Up to the first of the year we lost 41 per cent which we cannot account for. We made an estimate for the city stable based on what we have been receiving from a private stable, or a boarding stable, where we have had a meter set. We allowed the same amount, but on placing a meter there we found they were using over three times that amount, where there were no

carriages to wash, simply horses to water. We supposed that washing carriages would offset quite a waste, but we found it did not. The city stable with fifty-six horses has used over three times as much as was used in the boarding stable with seventy-five horses. I hope this season we shall be able to get at some of that waste, and possibly we can. We have taken our full rate consumers and have placed them on the same ratio with the metered takers; and for all stopped meters we find during the quarter, we make an estimate on the basis of the same quarter of the previous year, and call it the same number of feet.

MR. BRACKETT. I would like to ask Mr. Kieran if the 40 per cent includes the whole use by the city? That is, whether the 60 per cent which you have measured or can account for is simply what is metered, and the 40 per cent includes all other uses?

MR. KIERAN. The 40 per cent is the actual loss, what we can not account for after estimating for public purposes. That is the actual loss.

MR. STACEY. Perhaps some of that can be accounted for in the way we are trying to account for some of our water. For all our school buildings we get $6 a year. We came to the conclusion we would put on a meter at one of the schools, and the first three months it ran 21,000 cubic feet. We thought that was accounting for some of the water we could not account for otherwise.

MR. CRANDALL. Speaking about accounting for water used for public purposes, I think I can add a pretty good story which is true. Our public buildings and parks committee decided on the 31st of July last that they were being overcharged at the schedule rates, and that they would in the future pay the meter rate. We had for the previous year, and for the previous months of last year, had meters on the park services for our own information, although they had paid the schedule rate during that time. On footing up at the close of the season, I found that for the months since the 31st of July when they were paying at meter rates, they had used about one-fourth as much water as they did during the preceding months of the same year; I mean, the rate per day was about one-fourth the rate during the preceding months, and the preceding months were the wet months of the season. They had used during the period for which they were paying meter rates about one-fifth what they used the preceding season; I am speaking of the rate

per day each time. We find it is very difficult to make the individual consumer understand why he should practice economy, when he sees water being wasted in public places at the rate I have just spoken of.

MR. HOLDEN. I would like to inquire of Mr. Crandall what the cost of this motor was, and how much the expense of keeping it in repair was.

MR. CRANDALL. Our motor is a small one; it is for a 10-inch main. It was put in before I had anything to do with the water works, but if I remember rightly, it cost about $2,000. The cost for maintenance, that is the care of the machine, for no automatic machine will run without care, and the cost of repairs, charging it whatever gas is burned, and anything that is used at that place, has amounted to less than $400 per annum since I have been on the works. Mr. Richards has a much larger motor, and he probably remembers just what that cost.

MR. RICHARDS. Our motor is larger, and pumps more water. My recollection is that the motor cost about $5,000, and the cost of maintenance is about $300 a year.

MR. CRANDALL. In my cost for maintenance I am including the proportionate part of the fuel that is used for pumping water at the low service. The motor runs in either direction. We can make it run by pumping water into the reservoir, or it will run when the pumps stop; without any action on our part, it will automatically reverse itself. Mr. Richards' motor only runs one way, there is no occasion for running it the other way. In our case, when the motor is run by the pump, there is five pounds additional pressure, and a certain per cent of fuel used at the low station is properly chargeable to the high station, but in the figures is included the per cent of fuel which would be used did the motor run all the time, which it does not.

MR. FULLER. In Wellesley we meter all the water that is consumed, or attempt to, and I think during the month of December—if I had known this matter was coming up I would have looked it up a little more carefully—I think we accounted for 67 per cent of the water we supposed we had pumped. We do not meter the water as we pump it, as it goes into the mains, but I think in the spring we shall attempt to do that. This comparison is based on allowing, I think it is, 3 per cent slip on the pump, and using about

the full length of the stroke of the pump. I know we lose something by small leaks through the meters that is not recorded, but we have tested our pipe system and are sure that there are no large leaks there, probably there are some small leaks, and it seems to be quite a problem to account for this apparent discrepancy in the amount of water pumped and what is recorded.

MR. WHITNEY. Isn't it probable, Mr. Crandall, that your low pressure on this section accounts for the very large percentage which you can seem to find of the water pumped? What I mean is, is it not probable that on a regular water system with heavy pressure, dribbling ball cocks, the water for which is not registered by the meters, oftentimes accounts for a very large percentage of this water which is lost?

MR. CRANDALL. There is no doubt in my mind that an increase of the pressure would increase the amount unaccounted for.

LAYING A 24-INCH MAIN UNDER THE NASHUA RIVER.

BY HORACE G. HOLDEN, SUPT., NASHUA, N. H.

[*Read February 9, 1898.*]

The city of Nashua is located on both sides of the Nashua river near its junction with the Merrimack. It is fourteen miles above Lowell, and seventeen miles below Manchester. The entire water supply for domestic use, steam boilers and fire protection is furnished by the Pennichuck Water Works.

The water is taken from a system of ponds and reservoirs fed by springs and the Pennichuck brook about two miles north of the city, being pumped through two lines of cast iron pipe, 24-inch and 16-inch. These two lines unite near the center of the city into one 24-inch line, the whole length of the 24-inch pipe being about three miles.

In crossing the Nashua river the pipes are suspended under a "lattice bridge." Although the bridge has held the water pipes safely for forty-four years, an accident might at any time occur to the bridge; by which a large portion of the city would be left with a very limited supply of water. For this reason it was deemed advisable to lay a separate 24-inch pipe under the river and connect it with the main 24-inch near each end of the bridge, forming a loop, so that in case of any accident to the bridge the water supply could pass under the river, which at this point is about 250 feet wide, with an average depth of 18 feet.

Owing to difficulties about obtaining a right of way to the river, the crossing had to be made about 150 feet above the bridge, the submerged part requiring twenty-two lengths or 264 feet of pipe having the "Ward joint."

[A model of a "Ward joint" was here exhibited.]

You will notice by the model that the bell is larger and deeper than in the common joint, and that the inside of the bell is turned similiar to a hollow sphere, while the spigot has two ribs running

around the pipe. These ribs are seven-eighths of an inch less in diameter than the inside of the bell, so that after the lead is poured there will be seven-sixteenths of an inch of lead in the thinnest part of the joint, while the ribs serve to hold the lead in place and prevent the joint from pulling out.

The south bank of the river at this place had for many years been used as a dumping ground for the refuse from the neigbboring factories. This necessitated the grading of the bank, starting about fifty feet from the edge of the river and sloping into the river for several feet, in order to prevent too great a bend in any one joint. The pipes were put together on the slope, being laid on rolls resting on plank. The first pipe used had an ordinary bell end, which was plugged tight. The other end of the pipe had a "Ward joint bell," and into this the spigot end of the next pipe was firmly leaded, about one hundred and fifty pounds of lead being required for each joint. As fast as the pipes were put together they were secured from pulling apart by a heavy cable lashed twice around each pipe, and six to eight empty oil barrels secured to these lashings to keep the pipe from sinking. Then with a windlass on the opposite bank the line of pipe was gradually drawn across, the rear of the line being held by snub lines which prevented the pipe from going to the river any faster than the joints were completed.

After the submerged part was finished and the pipe line stretched from shore to shore, being held up by 175 empty barrels, the pipe was then filled with water from a neighboring hydrant. This caused it to gradually settle, and upon cutting the lashings to the barrels in various places along the line, the pipe slowly sunk to the bottom of the river, and then the line was extended from both banks to the pipes on the main street near each end of the bridge.

The unusual spectacle of a 24-inch pipe line being lowered to the bottom of the Nashua river drew a large gathering of spectators, and the Nashua bridge was crowded with people watching the operation, among whom was the ever present newspaper correspondent, and the next day the Boston *Post's* "Observant Citizen," who evidently was not up to date on submerged pipe laying, broke loose as follows: "I was in Nashua yesterday and was much amused, while waiting for a train, by watching the rather primitive methods of a crew of workmen engaged in placing a water main across the bed of the Nashua river. Wishing to suspend the pipe

until the divers could arrange the supports under them, they employed empty barrels to float the pipes. Unfortunately the casks had been used for oil, and as soon as the weight of the pipe was applied, the ropes would slip from the barrels, sending them bobbing around in all directions. The current did not particularly facilitate the efforts of the disgusted workmen in reassembling them."

The facts of the case were that the barrels were lashed to the pipes to lift them. When "Observant Citizen" saw the barrels, the diver was on the river bottom cutting the lashings and allowing them to escape. This was for the purpose of lowering the pipe to its place on the bed of the river. The work may have been primitive, but it accomplished the purpose for which it was intended, and the only workmen were the diver and his two assistants.

After setting 24-inch water gates at each end of the submerged line the street pressure, which at this place is about seventy pounds, was let on, and in order to test the line for any leaks two $\frac{5}{8}$-inch corporation cocks were tapped into one of the pipes on the south bank of the river. A test gauge was placed on one of these cocks, and from the other a line of 1-inch pipe was laid and connected with a service pipe from a neighboring building. On this line was placed a $\frac{5}{8}$-inch meter which had been carefully tested, also a force pump capable of raising the pressure to 100 pounds to the square inch. The first test showed a leakage of about two gallons per minute and on examination of the pipe line by a diver small leaks were found in several of the joints. These were then carefully caulked, and at the present time the leakage is greatly reduced—the last test showing about thirty gallons per hour. It is my intention next season to have the whole line perfectly tight.

The pipe for this job was furnished by the Warren Foundry & Machine Co. The work on the submerged portion was done by the well-known diver and contractor George W. Townsend of Boston.

DISCUSSION.

MR. CRANDALL. I would like to ask Mr. Holden if there was any preparation of the bottom made for this pipe line, before it was lowered into position?

MR. HOLDEN. The bottom of the river was very smooth; there

were no stones of any amount, and there was a hard gravel bottom on the south shore. On the north shore was a little mud, so the pipe settled down. We didn't have to make any preparation whatever, and as the pipe lies, I had it examined by one of my own men with a diving suit; he found every pipe was well bedded on the bottom of the river.

THE PRESIDENT. Mr. Brackett, I think you have recently had some experience in laying pipe across or under rivers?

MR. BRACKETT. I think some of the other members, who have done the work, can perhaps, tell better about this work, than I. I think Mr. Gowing can tell you about one section which has been laid.

THE PRESIDENT. We would be very glad to hear from Mr. Gowing. Perhaps Mr. Brackett could tell us how it was proposed to do it and Mr. Gowing could tell us how it was done.

MR. GOWING. We laid a pipe across the Malden river, but the pipe laying part of it was not difficult at all, because we put in a coffer-dam and pumped it out dry, and then we laid the pipe just as if it were on dry land. Where that can be done, of course, it is very much better than any Ward joint, or anything of the sort, I think. It is a good deal more expensive, it would have been more expensive to have laid the pipe across the Nashua river in the way we laid it across the Malden river, than to lay it as it was laid. But I think the Metropolitan Water Board has one satisfaction for the money they spent, and that is they have got a tight line. I wasn't there when it was tested, but they told me that the meter refused to work, and I don't believe they will ever have any trouble and if they get 10, 20 or 30 per cent loss, it won't be on our line.

MR. BRACKETT. We have laid three large lines of pipe across rivers, but I do not think at the present time I can give you full details of the work. If it would be of interest, I might tell you in a general way how the work has been done.

In crossing the Malden river, of which Mr. Gowing speaks, we considered that it was better to lay the pipe by means of a coffer-dam than it was to use flexible joints and lower the pipe into a dredged trench. It may be, perhaps, that there were peculiar circumstances in this case.

We had two crossings of the Charles river and one of the Mystic river. One of those on the Charles was about 600 feet in length, the other about 400 feet, and the one on the Mystic was 1,200 feet.

They are all in connection with 48-inch pipe lines, and we have used a double 36-inch pipe line at each river crossing, to prevent the entire loss of the main in case of any leak on one of the lines crossing the river, and also for convenience in doing the work. The pipes which have been used, the pipe being laid in salt water, have been made very heavy; the 36-inch pipe is 1.65 inches in thickness, and weigh 677 pounds per foot, which is very much heavier than is used even for 48-inch pipe.

There were three types of joint used on the lines. One is the ordinary joint, with the exception that in place of one lead score there were three, for more firmly holding the lead.

The second type had a turned spigot end, with a very slight taper, about a sixteenth of an inch in five inches. And in the socket or bell of the connecting pipe the lead was cast, and then the spigot end was withdrawn and jointed under water afterward.

The third type was a ball and socket joint similar to the Ward joint, the difference being that the lead is cast into the bell rather than being cast on to the spigot, so that when the joint turns the lead is not drawn out of the bell. Flexible joints were only used at changes in the vertical line of the pipe.

The pipes were made up on the shore in sections, generally of six lengths of pipe, and at one end of each section was a turned tapered spigot, the bell at the other end having the lead cast in to receive the spigot end of a section which had already been laid. The whole section was suspended on a truss hung from derricks on a scow, and then lowered into position, in a dredged trench in the river. The diver entered the spigot end of the tapered pipe into the bell, or into a guide which was bolted to the bell end of the pipe which was being lowered, and then by hydraulic power, applied through a cylinder and piston attached to the truss, the pipes were drawn together, and they were afterwards caulked by a diver. That is in general the method in which the work has been done.

At the crossing of the Mystic river, the entire length of 1,200 feet of pipes were laid on a pile foundation, consisting of a 10x10 cap placed crosswise of the line of pipe back of the bell of each length, and supported by two spruce piles. On the other lines the pipes rest in the earth for the greater part of the distance, but are on piles near the shore where there was a soft bottom.

MR. WINSLOW. Weren't those bottoms prepared for the pipes

independently of the piling, so as to carry them below the bottom of the river, so they were covered with earth?

MR. BRACKETT. The pipes were all laid in dredged channels, and were afterwards covered, so that they are below the bed of the river and not liable to be damaged by any vessels even grounding on them.

MR. HOLDEN. What amount of leakage do you get on your submerged pipe in the Charles river?

MR. BRACKETT. I stated I could not give you all the details. I know there has been some leakage, but I haven't the figures. However, they are reasonably tight.

MR. HOLDEN. In making out the contract for laying the pipe, of which I have spoken, I used the same specifications that Mr. Brackett used on the Charles river pipe—that is, that the leakage should not be over a tenth of a gallon per running foot per hour, which in our case would be 26.4 gallons per hour. At present the leakage does not amount to any more than that; it is just about that now.

MR. GILBERT. I might relate a little experience I had with laying a 12-inch pipe in the water some ten years ago. I wanted to lay it about 100 feet into a pond, so as to get the end of the pipe out into deep water. I made arrangements for putting it together on shore, and then shoving it out. I made preparations by getting oil barrels, making a number of rafts, etc., and got everything in readiness. We got the pipe started out into the water, and attached the oil barrels, and as we put in a piece of pipe we would shove it out. It worked nicely, and I was very much pleased with our success, as I had anticipated a great deal of trouble in keeping the pipe on top of the water. We had the end of the pipe plugged up tight, and after getting it out about 100 feet, we got on to the rafts and cut loose our oil barrels. After we cut the oil barrels all away, and got the rafts out, our pipe still laid on the top of the water, and we couldn't sink it, it wouldn't go down anyway. Finally we knocked the plug out of the end, and the pipe slowly sank to the bottom.

THE PRESIDENT. I am told that Mr. Crandall has had considerable experience in laying pipe under water.

MR. CRANDALL. We laid about three miles of 24-inch on the bottom of Lake Champlain, in 1894. Mr. Falcon of Evanston, Illinois, had the contract, being the lowest bidder, and we used one

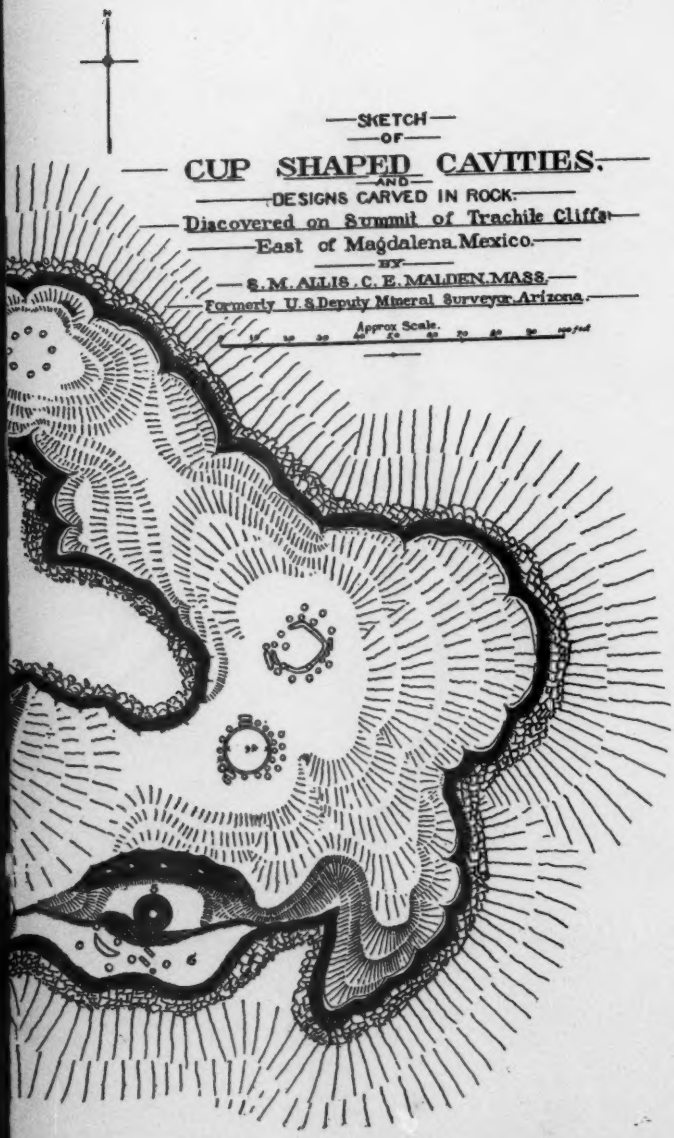
of his patent joints on every six lengths. I think he could have laid 600 feet a day if he had wished to; but he did not want our citizens to know he had such a snap, I think, so he did not work quite as fast as that. The bottom of the lake is sand for the entire distance, overlaid with a more or less thin layer of mud, and experiments indicated that the pipe would settle through the mud on to the sand; and in lowering the pipe it was found that it did immediately reach a bed. And at the time of laying the last lengths, which was several months after the laying of the first, the first lengths had not settled any from their first position.

There were two summits in the three miles, and openings were left at those summits, by tapping a brass tube into the top of the 24-inch pipe at as near the summit as we could get it, and tapping small holes through the brass tube. If I remember rightly, there are four one-eighth inch holes through the brass tube at each of the summits. The conduit when completed was tested by filling with water under 20 pounds pressure. I do not remember just what we specified for leakage, but the contractor was inside the limit. Since then tests have been made which showed that the leakage was diminishing. It was tested in 1895 and in 1896, and in 1895 the result was better than in 1894, and in 1896 it was better than in 1895. And when I say "better" I simply mean better; I do not mean to say very much better, but it was not worse.

MR. WHITNEY. I would like to ask Mr. Crandall how the joint he used, the flexible joint, differs from this Ward joint which has been shown here today?

MR. CRANDALL. The Falcon joint on the spigot end is spherical, and the bell end has a flanged cup into which this sphere projects, and there is a ring which it is necessary to slip on over the back side of the spigot. It will not pull over the turned sphere of the spigot even with no lead in. After slipping it over the spigot from the back side it is leaded. Then the flange on the ring is bolted to the flange of the bell, which is leaded to the other length to which it is to be joined under water. The joint made under water is a flange joint. In our case, which was a 24-inch pipe, if I remember rightly, there were twenty-six bolts, and, I think Mr. Falcon did the tightening up of the twenty-six bolts in a little less than twenty-six minutes. I went down afterwards to see if he had done it, on a bet, and I was unable to make it any tighter on any one of the bolts.

CATTLE CORRAL.
HIGHEST POINT. NEARLY FLAT
FIFTY FEET ABOVE PLAIN.


N
SKETCH
OF
CUP SHAPED CAVITIES.
AND
DESIGNS CARVED IN ROCK.
Discovered on Summit of Trachile Cliffs
East of Magdalena Mexico.
BY
S. M. ALLIS. C. E. MALDEN. MASS.
Formerly U. S Deputy Mineral Surveyor. Arizona.
Approx Scale.

EXPERIENCES IN THE "ARID SOUTHWEST."

BY SOLON M. ALLIS, C. E., MALDEN, MASS., FORMERLY U. S. DEPUTY MINERAL SURVEYOR, TUCSON, ARIZONA.

[*Read February 9, 1898.*]

Having spent some years mining and surveying in the extreme southwest of Uncle Sam's territories, and in Northern Sonora, Mexico, I was much impressed by the difficulties experienced in getting water for irrigation, and in many places for camp use. This difficulty is mainly caused by the physical features of the country which I will briefly notice.

Although Arizona has in its northern area an extreme elevation of 6,000 feet above the sea and mountain ranges that originate never failing streams of good size, such as the Gila and Salt rivers, yet we find a very large area in the southwest where the low lying plains rise from 12 feet above the sea at Yuma, to 2,500 feet at Tucson, distant 220 miles south of east. These low lying plains are diversified by small detached mountain peaks and ranges of no great altitude, but of forbidding aspect, as bare and rocky they glisten in the terrific heat of the summer months.

These give rise to different drainage areas, and the dry "arroyos," devoid of water during a large portion of the year, become in the wet season full of water, which sometimes comes from cloud bursts, resulting in raging torrents, generally, however, of very short duration.

On the eastern portion of this large area, and where the elevation becomes 10,000 feet and upwards, some of the streams have water the year round, as, for instance, the San Pedro which flows northerly into the Gila, its valley being east of the Whetstone mountains. Others disappear for miles, soon after the rains cease, and are only found flowing continuously at intervals. Among the latter is the Santa Cruz, which, rising in Arizona, runs south into Sonora, then turning west and north, returns to Arizona and empties into the Gila.

This river disappears near the line as it reenters Arizona and

reappears above Tubac, about twelve miles north of the line, and remains at the surface several miles, then it sinks out of sight and comes to the surface at a point about forty miles distant and about eight miles south of Tucson, not far from the old church of San Xavier, built over 100 years ago for the Papago Indians, upon the site of another that had stood 150 years. It now appears for about sixteen miles, and about eight miles north of Tucson again disappears for ninety miles, being found 150 feet below the surface about fifteen miles north of Tucson.

The reason of this eccentric action is found in the fact that the valley of the Santa Cruz, everywhere wide and quick sloping, is composed of coarse gravels, which being nearly destitute of clay, permits the water to seek a lower level until it flows along the bed rock. At Tubac and Tucson a series of trap dikes across the valley, nearly at right angles to the stream, making a natural dam that brings the water to the surface. This accounts for the fact that Tucson has been for years an oasis in the desert, and was a permanently settled town of Pima Indians, when first visited by Coronado in 1539.

Below Tucson, where the river commences to sink, the farmers dig long ditches, graded slightly as possible, and bring the water out of the lower country for quite a distance. Adopting this hint from nature, a number of California companies have secured good supplies by digging deep trenches across the narrow valleys or canyons to bed-rock, then building a tight wall of masonry therein, thus bringing the subterranean supply to the surface.

When I first went to Arizona, I found it to be the opinion of the settlers that water must be searched for by digging down to the underground stream in the middle of the valley, as was the custom and is now by the Mexicans.

Many fine grazing tracts were unoccupied for want of water, especially upon the foot hills, where the best gramma grass was found and generally much desired shade. Some one thought of testing the slope near the foot of the mountains, and plentiful supplies were thus found in many places, of course depending as every where else upon the water shed above.

The Southern Pacific Railroad Company have experimented with artesian wells and, while some have been failures, enough have been successful to warrant attempts all along the line.

The great Sulphur Spring Valley, sixty miles wide, and shunned

by prospectors and travelers on account of its dearth of water, has been found to have plenty of water almost everywhere, from 30 to 40 feet below the surface, and within a few years the great Pierce mine was found in this valley This mine was bought by Senator Penrose for $60,000, and is no producing $450,000 per month.

While developing some mining property west of Querobabi, on the Sonora railroad, and about ninety miles below the boundary line, I found an extreme scarcity of water. The mines were inside an elevated rim of low hills, some nine miles from the station, and about 500 feet higher.

The railroad was located at the lowest point of the wide valley and near a dry arroyo. The Mexicans had dug a well near the depot 300 feet deep, without getting water, and the attempt was abandoned. To supply their employees, the railroad company sent water in large iron tanks from a point some thirty miles distant. For some time I purchased from four to six barrels a day for camp use, paying two cents a gallon, and hauling all the way up hill to the camp over a sandy road. After some study of the surroundings, I determined to sink a well, although the Mexicans laughed at the idea. Selecting a point quite near the arroyo where it debouched from the circle of hills, I sunk a shaft four feet by five feet, blasting through porphyry all the way, until I reached a point ninety-two feet below the surface, when the water which had begun to come in at seventy feet in small quantities, now came in so fast I went no farther, and the next day we had ten feet of fine water. When the rainy season came my well had seventy-two feet of water in it and was the wonder of the Mexicans. The main road, in use for more than a century, was changed so that travelers could camp at my well, and "Allis Pozo" is in use today and the only well of its kind for hundreds of miles. I would say here that when the Mexicans dig such deep wells in the valleys as I have mentioned (and I have seen many from one to two hundred feet deep), the soil is so firm that no curbing is needed.

A rude windlass is erected over the well rigged with a grooved wheel about eighteen inches in diameter, made of wood, over which a raw hide rope is passed. At one end a bucket made of rawhide, holding about half as much as a flour barrel is fastened, and the other end tied around the horns of a steer, which thus makes a primitive hoisting machine, used also to hoist the water

when the well is completed. The Papago Indians who inhabit the driest portions of Arizona and Sonora have another way of procuring, or I might say, saving water on these arid plains. Selecting a place where the slope is pronounced, they dig long trenches or throw up a ridge of earth diverting from the lowest point at an angle of forty-five or sixty degrees. At the lowest point where the water is collected the earth is thrown up from both sides, making in some cases a dam four or five feet high. The inside is carefully plastered with wet adobe soil, making a small pond. The heavy rains (if they happen to have any that season) fill these ponds, and this supplies them sometimes until quite well along into the dry season. When this is exhausted they migrate as usual to springs in the mountains, known to them, where they remain until the next wet season. As the Indians and the herds use out of the same pond, no pains being taken to keep the cattle from wading in it, the condition of the water when nearly exhausted can better be imagined than described, and I am afraid would lead to a remonstrance from the Massachusetts Board of Health, if they ever saw it.

Myself and a companion, named John McDonald, once lost our way in the Papago country, while attempting to find a mine near the Mexican border. We were out of water and nearly choked, when at dark we stumbled on to one of these abandoned rancheros. By carefully exploring the deep holes in the clay, made by the feet of the cattle, we found about two quarts of water from a late shower. This we strained two or three times and made some coffee, putting in a good deal of sugar. It came the nearest to some of my war experiences in the swamps of North Carolina of anything I ever met since in the way of bad water. Our horses had to go without and we traveled twenty miles the next day before we found water.

Starting out one morning from Nacosari canyon, in eastern Sonora, and among the foot-hills of the Sierra Madre, a party of us searched for many miles for an old abandoned mine of the ancient days.

I carried a canteen holding two gallons of water, but by noon it was all gone, as I had a bad attack of fever and ague, and I had shared with another member of our party. The sun was blazing hot, and by 4 o'clock we were all out of water, and pretty well used up, and turned towards camp.

Crossing a steep, high hill, we saw in the valley two large, green trees said to be mountain mahogany. One of the Mexicans said we would surely find water there. Our mules seemed very willing to go all at once, and we soon reached the place. I found under the trees, which were near a high ledge of rock, two tanks as they are called, being deep holes in the rocks about four feet in diameter and nearly the same depth, which had been filled by the rains of many weeks previous. The top of the water was covered with a thick, green scum. On dipping this out, the water seemed alive with black bugs resembling our beetles. I slapped the surface with a quart cup which caused them to scuttle away, and taking a drink, I found the water perfectly pure, and it seemed to taste as well as any I ever drank. It was accidentally finding some tanks like these on the desert west of Tucson that saved the lives of the men under General Kearney, who marched from Santa Fe to Los Angeles at the time we first occupied California.

As I intimated when I began, I might tell you some experiences not exactly in the line of superintending water works, and if I have not already exhausted your patience, I will give you in closing an experience I had in looking up some curious rock sculpture, by some ancient dwellers in Sonora.

While engaged in opening the Sonora mines, I was also developing some property in the Sonoita valley, about twenty miles north of Nogales, a small town on the railroad, where it crosses the boundary line. Thus I was obliged to make frequent trips over this railroad, which connects Guaymas with Benson and Tucson, Arizona.

While in Tucson, on one of these trips, I met a gentleman who had been looking for coal in Sonora. He informed me that while examining the country southeast of Magdalena, he had came across what he called the "Indian rock sculpture," about sixteen miles distant. He described rooms cut in the rock, grapes in bunches carved on snow white walls and circular projections smoothly carved and beautiful to behold. All this so excited my curiosity that I determined to visit the place at the first opportunity.

This did not occur until March, 1883. I had met at Magdalena a Mr. Wells, who had accompanied my informant on his coal hunting expedition. I had arranged with him to be my guide whenever I could stop off, and on March 21 I left the mines at Querobabi, for the station, arriving there about dark. Before leaving camp, I

was informed that a large band of Apaches, lurking in the Sierra Madres, had made a descent near Carbo, a town some twenty miles south, and were driving off all the cattle they could gather. Some of my men were quite alarmed, and feared our camp might be attacked. I assured them that there was no danger, as I had never known the Apaches to cross the railroad, and we were nine miles west. On reaching the station I found a special train with Mr. Seeley, the superintendent, the chief engineer and Mr. Hunt, the paymaster, on their regular trip to pay off, and I went to Magdalena with them. Our train had barely left the station, when as I afterwards learned, several men bringing silver from the San Augustine mine, situated some twenty miles east, were fired upon by a party of Apaches, hidden in the bushes a mile from the station. The men reached the station, with no casualties except wounding one of the mules.

Arriving at Magdelena about 9 o'clock, I went to the hotel and there found Wells, and arranged for an early start. Daylight found us on our way each on a good horse and well armed. Our way for the first eight miles followed the road over a high and rugged mesa, covered by prickly pear and giant cactus. After leaving the valley, where the abundant streams of water had made the existence of a town possible, the country assumed a forbidding aspect. Sage brush, mesquite and an occasional palo verde were the only vegetation, while tall crosses or large heaps of stones marked no less than seven graves of travelers, killed by the Indians, within as many miles.

One of the saddest scenes in Arizona and Sonora is the solitary grave found here and there all over the country, marking the spot where some lonely traveler or wandering prospector has fallen a victim to the murderous Apache. In southern Arizona it is said over eight hundred such graves dot the wayside.

Eight miles from Magdalena we left the road, taking a blind trail for eight miles more, leading over low ranges and a rugged country almost destitute of vegetation, to our destination. We found ourselves about 11 o'clock in a wide, grassy valley, enclosed by high hills, behind which towered the Sierra Madres which form the backbone of Sonora. A small brook running down through the valley and the green grass bordering it looked very pleasant after the tedious ride of the forenoon.

Here we found the first carvings, which instead of having been made by Indians were unmistakably wind carvings. Some of them were so beautiful and curious that I was not surprised that they had been supposed to be of human origin. The view for a long distance up the wide valley was unobstructed, except by a few detached cliffs of white trachite. The upper surface of these cliffs was of a much harder texture than that immediately below, as if the surface of melted outflow had been hardened by the air, and some of the cliffs were harder clear through than others. The upper layers were of a brown color, while the portions below, which had been worked out by the wind was as white as snow. The texture of the underlying rocks in the softer cliffs was somewhat harder than chalk, while imbedded were thousands of sharp edged grains of quartz, which becoming loosened were blown about by the wind, adding their cutting qualities to the erosive action of the wind-borne dust.

In some of the cliffs the rock was cut out in a beautiful manner, leaving a projecting roof hollowed out and as smooth as if cut by a skillful artist. In others, hard, concretionary substances stood out in relief, resembling a bunch of grapes. These after awhile becoming detatched, fall to the bottom of the cliff, covering the ground. These concretions were flint like and round, varying in size from that of a bullet to that of a butternut, and so hard that when placed upon an anvil, a severe blow with a sledge would hardly crack them.

In one of the cliffs the projections had been taken advantage of by three herders from Magdalena, who were taking care of a bunch of cattle feeding in the valley. A wall of boulders was built under the edge of the projecting rock, making a comfortable room eight feet wide and high and about twenty feet long.* The shape of one of the larger cliffs, shown in plan and elevation, was such that a large and secure enclosure was made by putting up a pair of bars, and it was used as a corral for the cattle. We made some examinations and picked up a few of the "grapes" of stone already described, before dinner.

After feeding our horses and taking our lunch, I suggested that we climb to the top of the highest cliff, about 40 feet. This we

*Mr. Allis distributed drawings and sketches illustrating these wind carvings and cup-shaped carvings mentioned farther on.—Ed.

did, not without considerable effort. There we found on the hard surface of the smooth, gently rounded slopes and flat places, another and quite a different kind of carving, evidently made by human hands. To my companion, these were quite as new as to myself, and I can find no evidence that they were ever noticed earlier than at our visit.

These carvings were cup-shaped, with curious channels in some places taking the place of the cups. The channels were mostly about four inches deep, and about as wide, but a few were somewhat larger. As will be noticed on the larger sketch, the circular rows of holes were in some cases enclosed by the channels, in others the reverse, while still other designs are channels without the cups. These channels were generally V shaped, although some were hollowed out more like the letter U.

Near the upper left hand corner of the sketch are seen four projections of solid rock, standing nearly two feet above the level of the cliff, each with a deep, well-carved hole in the summit about eight inches in diameter and about the same in depth. These holes were black with age, apparently, though fire may have done this.

On a shelf or bench of rock and some four or five feet below the top of the cliff, on which the cups were carved, was found what seemed to be a cistern, about eight feet in diameter and about four feet in depth, cut beautifully round, reminding one of the pot holes found in the rocks below the water-falls of many of our New England rivers. That this was a cistern seemed to be indicated not only by its position and evident human workmanship, but also by a narrow channel cut from its edge at top to the edge of the cliff, so that if it filled with water it would flow to a second bench below, where again we found cup and other carving, one of which resembled a crescent. In the side of the upper bench above the cisterns were found five cavities hollowed out, some eighteen inches or two feet long and nearly as deep. These seemed to have been designed as places of deposit for small articles.

I was much puzzled to account for these carvings, and on my return to Tucson mentioned them to Dr. J. C. Handy. He had a short time previously received a book by Charles Rau, published by the Smithsonian Institute, in 1882, describing the cup-carvings of Europe and Asia, which he showed me, and I at once saw that the Sonora carvings were of the same character as those the book de-

scribed. These carvings are so similar to those found at the Temple of Chandelahar, India, that I think we may without mistake assign them to the same origin, namely, emblems of the Phallic worship of the ancient Aryans of India. No cup-carvings like those found in Europe and Asia, except the scrolls designated as type 7 in his book, seem to have been known to Rau, as existing in this country, and those found on a large boulder in Santa Barbara county, California, and the latter he called mortar cavities. Detached holes of the Santa Barbara character are common and generally supposed to be corn-mills or mortars, and are much larger than the cup-carvings, generally eight inches in diameter and as deep.

In southern Arizona, the Initial monument of the Barba-comori grant surveyed by myself in 1882, is built around a post set in one of these corn-mortars, found on the summit of a magnetic rock, on the edge of a cienaga at the center of the grant. I observed a row of these corn-mill holes under a large projecting rock, a few miles south of Tucson, Arizona, where evidently the families of the Indians collected in the shade to pound their corn. From this point a fine view was had of the valley of the Santa Cruz river. These holes were all large and in the hardest rock.

The conclusion as indicated, if correct, throws another ray of light upon the vexed question of who first settled the Western Hemisphere, and points to a race far antedating the Aztecs or Toltecs, whom Cortez found already an ancient race of people in Mexico.

We were fortunate in selecting the day of our visit, for on the day following the same band of Apaches, spoken of as being at Querobabi, reached this place and the three herders were all killed, as was also the owner of the cattle, who, unfortunately, went there the same day.

FIRE PROTECTION, BY WHOM AND HOW IT SHOULD BE PAID?*

BY JOEL FOSTER, SUPERINTENDENT, MONTPELIER, VT.

If a private corporation owns the franchise of a water system in a village or city, it is universally understood at the outset that the village or city is to pay a stipulated price for hydrants, watering troughs, stand pipes for sprinkling streets, flushing sewers and for public buildings. These expenses would be paid by an increase tax on the grand list, and who claims that it would not be just and right?

On the other hand, the village or city owns its water system. Is there any reason why an appropriation from that village or city, equal to the sum paid to the private company for the same benefits received, should not be made? On a careful investigation of this question I believe that every considerate person would answer, No.

It is universally conceded by all engineers and contractors of water works that the cost to construct for a good fire protection is fully one-third more than is necessary for domestic and sanitary purposes. Then why not have the property protected bear its due proportion of the burden of expense, instead of wringing it out of the patrons of the city water? We often hear the remark, "The water works will pay for themselves; why make the appropriation? It is only taking money from one pocket and putting it into the other." Is this assertion true?

In making no appropriation for the hydrants and other public uses, and relying wholly on the domestic and business receipts of the water works to pay their cost and expenses, who pays for fire protection and the other luxuries named? I will try to give figures below that will demonstrate the facts.

*From the Annual Report, Montpelier, Vt., Feb., 1898.

There was printed in the city papers last year a statement giving the total grand list of the city in 1897 ($38,004.89), and the lists of individuals.

The grand list of taxpayers having a list of $100 and over aggregated	$16,096.10
Over $50 and under $100	6,982.15
Less than $50	14,926.64
The water receipts for the business year were	11,313.86
Of this sum I find that the division of the taxpayers having a grand list of $16,096.10, paid for water service	2,820.00
The second division, $6,982.15, paid for water service	1,676.50
The third division, $14,926.64, paid for water service	6,817.36

To tax these several divisions of the grand list, as shown above, on the basis of their contributions to the gross water receipts ($11,313.00), the percentage assessed to each division would be as follows:

Taxpayers having a grand list exceeding $100	$0.175	on the	dollar
Taxpayers having $50 and less than $100	.24	"	"
Taxpayers having less than $50	.45	"	"

which shows at a glance the unjust discrimination of the taxation to the varied owners of city property.

To illustrate further the inequality of paying for fire protection and other public uses of city water by throwing the whole burden of such expenses on to private consumers of water, I will take the case of individuals.

The water system asks the city of Montpelier to appropriate $2,300.00 a year for hydrants, watering troughs, stand pipes, etc.

This sum was voted at the annual village meeting December 5, 1887, and was paid over to the water system annually till 1896. The city council then refused to make the appropriation, compelling

the private users of the city water to bear the entire expense for public uses.

Under this new policy, I find by computation that the percentage paid by the division of taxpayers, whose grand list is $16,096, is 3.6 per cent., or	$ 579.45
That those whose grand list aggregates $6,982, is 5 per cent., or	349.10
That those whose grand list aggregates $14,926, is 9.15 per cent., or	1,365.73
Loss by omitting fractions	5.72
	$ 2,300.00

That is, the division of taxpayers whose grand list is $100 or over pays for fire protection 3.6 per cent. of their grand list.

Those whose grand list is less than $100 and over $50 pay 5 per cent. of their grand list.

Those whose grand list is $50 and under pay 9.15 per cent. of their grand list.

This is a very unequal taxation.

The inequality of taxation for fire protection under the new policy of the city is further shown thus:

Mr. A. has a grand list of $200, pays $12 water tax.

Mr. B. has a grand list of $20, pays $12 water tax.

By this showing Mr. A., with his grand list of $200, contributes no more to the general receipts than Mr. B., with only a $20 grand list.

Is there any reason or justice in this division? Why should not Mr. A., with his $200 grand list, pay more for his fire protection than Mr. B., with only a grand list of $20?

The conclusion of the whole matter is, that putting the estimated cost of water for fire protection and other public uses into the regular expenses of the city, to be paid, like every other expense, on the grand list, is the only way to equalize taxation for the purposes named.

STATISTICS

FOR THE YEARS

1895 and 1896.

IN FORM ADOPTED BY THE

New England Water Works

ASSOCIATION.

Compiled by the Editors.

1895—I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Construction.	By whom Owned.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. Coal Used.	Per Ct. Ashes.	Price per Ton of 2240 Lbs.
1	Attleboro, Mass...	1873	Town.	Well near Seven Mile River.	Pump to S. P.	Blake & Deane.	Bituminous.		$4.60
2	Bay City, Mich....	1872	City.	Lake Huron.	Direct Pumping.	Holly.	Bituminous.		
3	Brockton, Mass....	1880	City.	Storage Reservoir	Pump to S. P.	Worthington.	Bituminous.	8.44	4.74
4	Burlington, Vt.....	1867-8	City.	Lake Champlain.	Pumping.	Worthington.	Anth. Mill S.		4.65-4.78
5	Concord, N. H	1872	City.	Penacook Lake.	Gravity and Pump to R.				
6	Fall River, Mass..	1874	City.	Watuppa Lake.	Pump to S. P. and Tanks.	Worthington & Davidson.	Bituminous.		
7	Fitchburg, Mass...	1871-2	City.	Storage Reservoirs.	Gravitation.				
8	Lynn, Mass.....	1872	City.	Storage Reservoirs.	Pump to R.	Morris & Loretz.	Bituminous.		4.55-4.62
9	Middleboro, Mass.	1885	F.Dist	Large Well.	Pump to S. P.	Deane.	Bituminous.		4.75-4.50
10	New Bedford, Mass	1866-69	City.	Storage Reservoir.	Gravity and Pumped to R.	Quintard and Worthington	Bit. & Anthracite.	12.16	4.20-4.50 4.12-4.19
11	New London, Conn	1872	City.	Lake Konomoc.	Gravity and Pump to T.	(Water Motor.)			
12	Newton, Mass	1876	City.	Filter Basin and Driven Wells.	Pump to R.	Blake & Worthington.	Bituminous.	6.00	4.15
13	Oberlin, Ohio.....	1887	Vil'ge.	Vermillion River.	Pump to S. P.	Deane.	Bituminous.		2.24-2.35
14	Plymouth, Mass...	1855	Town.	Great and Little South and Lout Ponds.	Gravity and P.	Worthington.	Bituminous.		4.25
15	Reading, Mass...	1890-1	Town.	Filter Gallery	Pump to S. P.	Geo. F. Blake.	Bituminous.		5.00-4.90
16	Springfield, Mass..	1873-5	City.	Impounding Reservoirs.	Gravitation.				
17	Taunton, Mass....	1876	City.	Elders Pond.	Gravity and D. Pumping.	Holly & Allis.	Bituminous.	3-7	3.60-4.00
18	Waltham, Mass....	1895	City.	Filter Basin.	Pump to R.	Worthington.	Bituminous.	11.00	
19	Woonsocket, R. I.	1884	City.	Crooks Falls Brook	Pump to R.	Worthing'n & Deane	Bituminous.	6.32	4.35
20	Yonkers, N. Y....	1874	City.	Grassy Sprain Brook.	Pump to R. & S. P	Wright & Worthington.	Anthracite.	12.25	4.34

1895—I. GENERAL AND PUMPING.—Continued.

Number.	3. Coal Consumed for the Year, Lbs.	4. Lbs. of Wood.	5. Total Fuel Consumed for the Ye'r Lbs.	6. T'l Pump'ge for the Year in Gallons.	7. Av'ge Static Head ag'st Pumps.	8. Av. Dy'mic Head ag'st Pumps, ft.	9. No. Gallons Pumped Per Lb. of Coal.	10. Duty in Ft. Lbs. Per 100 lbs. of Coal, No Deductions.	11. Cost per Mil'on Gal. Pumped into Res'voir Fig. on Pmp. Station Ex's.	12. Cost per Mil. Gals. Rai'd 1 ft. High. Fig. P. Sta. Ex	13. C'st pr Mil. Gals. P'm'd into Res'vr Fig on To'l Main'ance	14. C'st pr Mil Gal. r'sd 1 ft high Fig on Total main'ance
		3.										
1	465,993	1,000	466,993	109,808,840	160	175&188	236	36,900,000	$17.40	.0927	153.50	.817
2	3,220,140	49,329	3,269,469	1,122,363,460		113			6.73	.0595	43.82	.3871
3	505,185	225	505,410	400,974,405		43	793.7	28,451,641	7.40	.172	87.60	2.03
4				324,158,575	289	316			27.50	.087	141.53	.447
6	3,769,920			1,155,775,756		186			11.66		119.67	
8	436,500 1,723,799	222	436,500 1,724,465	344,707,090 1,251,053,100		160.68 160.47	789.7 725.5	105,826,355 97,091,511	5.88	3.66	76.65	.477
9	456,580		456,580	77,833,000	180	201	170.58	28,571,637	34.93	.174	89.47	.445
10	2,373,000	371	2,373,371	1,707,559,266	125.4 125.1 to 125.6	127.7 126.4 to 134.9	658 520 807	74,007,887 54,770,422 85,972,256	6.93	.530	40.93	.31 24/100
12	1,813,900	10,000	1,823,900	662,307,000	234	258	363	107,000,000	10.10	.039	156.3	.61
13	298,930		298,930	27,998,000	80	80	93.7	6,249,000	43.97	.55	164.20	2.05
14	2,181,600		2,181,600	103,118,400	65	66	471.72	25,965,355	14 55	.223	90.97	1.38
15	388,023		388,023	72,375,448	219	240	186.7	37,592,023	35.50	.147	178.51	.743
17	1,029,650		1,029,650	419,162,504		77.4	586.16	37,837,519	12.04	.155	163.55	2.11
18	1,648,900		1,648,900	445,972,320	164	190	271	43,084,870	19.92	.105	101.36	.53
19	872,477	317	872,787	225,587,860	238.4	239.5	258	52,248,733	15.15	.063	126.82	.53
20			4.230.266	1,166,751,521	185		276		11.38			

Number.	Name of City or Town.	Receipts from Consumers.				
		A	B	C	D	E
		Rates Domestic.	Rates Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.
1	Attleboro, Mass	$	$	$ 14,188.00	$	$
2	Bay City, Mich	17,514.55	4,891.76	22,406.31	413.99	22,820.30
3	Brockton, Mass			43,768.26	100.00	43,868.26
4	Burlington, Vt	34,161.77	5,431.62	39,593.39	3,161.57	42,754.96
5	Concord, N. H			55,239.77		
6	Fall River, Mass			117,130.47	326.00	117.456.47
7	Fitchburg, Mass	46,214.36	14,334.33	60,548.69		
8	Lynn, Mass	135,906.71	44,306.80	180,213,51	5,359.37	185,572.88
9	Middleboro, Mass	7,451.80	3,204.14	10,655.94	40.92	10,696.86
10	New Bedford, Mass	79,148.69	7,001.36	86,150.05	120.00	86,270 05
11	New London, Conn			38,634.05		38,634.05
12	Newton, Mass	74,149.31	7,800.00	81,949.31	4,016.08	85,965.39
13	Oberlin, Ohio	3,408.52	435.45	3,843.97	167.00	4,010.97
14	Plymouth, Mass	17,038.44	676.00	17,714.44	519,86	18,234.30
15	Reading, Mass	6,575.39	121.98	6,697.37	103.99	6,801.36
16	Springfield, Mass			173,840.65	33,448.40	207,289.05
17	Taunton, Mass	37,251.47	11,770.09	49,021.56	432.10	49,453.66
18	Waltham, Mass	49,870.21	5,667.16	55,537.37	4,531.35	
19	Woonsocket, R. I	26,868.02	7,562.38	34,430.40	101.21	34,531.61
20	Yonkers, N. Y	76,504.46	30,661.15	107,165.71	3,659.05	110,824.76

Number.	Receipts from Public Funds.					K	AA	BB	Miscellaneous Expenses.	Total Maintenance.
	F	G	H	I	J					
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.	Gross Receipts.	Management and Repairs.	Interest on Bonds.		
1	6,800	300.00		$ 225.00	$ 7,325.00	$ 21,513.00	$ 6,434.28	$ 10,400.00	$	$ 16,834.28
2					27,110.00	49,930.30	22,067.64	27,110.00		49,177.64
3	3,000.00					46,868.26	8,826.30	26,300.00		35,126.30
4	6,140.00		1,509.00	270.00	500.00	51,173.96	34,503.43	11,375.00		45,878.43
5					530.76	55,570.53	3,445.85	27,150.00		30,595.85
6					35,000.00	152,456.47	50,147.83	100,704.99		150,852.82
7							18,298.58			33,693.36
8						185,572.88	51,147.43	71,182.67		122,330.10
9						12,696.86	4,189.14	2,774.50		4,189.14
10					25,600.00	111,870.05	34,295.39	35,600.00		69,895.39
11					24,540.00	63,174.05	6,709.22	24,540.00		31,249.22
12	14,600.00	991.60	2,550.00	983.40	995.00	106,085.39	16,020.25	87,500.00	4,148.28	107,668.53
13					2,873.23	6,884.20	1,897.15	2,700.45		4,597.60
14						18,234.30	5,105.59	4,276.00		5,105.59
15	3,300.00				3,900.00	14,001.36	4,919.74	8,000.00		4,919.74
16	15,860.00	1,850.75	4,580.50	3,910.30	25,000.00	259,405.60	18,478.33	97,750.00	3,552.18	119,971.67
17	3,500.00	2,063.89	800.00	521.73		75,076.00	20,550.06	48,003.00		68,553.06
18						59,968.72	29,119.70	16,186.65		45,306.35
19	14,372.50	1,205.70	1,873.80	919.87	10,447.68	63,351.16	10,554.95	18,054.90		28,609.85
20	16,290.00				2,636.07	127,114.76	34,763.60	71,083.33	6,968.37	112,815.30

1895.—III.—CONSUMPTION.

Number.	Name of City or Town.	1	2	3	5	6	Percentage of Total Consumption Metered.	7	8	9	10
		Estimated Population.			Quantity used through Domestic Meters—Gals.	Quantity used through Man'f'ring Meters—Gals.		Average Daily Consumption, Gallons.	Gallons per Day.		
		Total at Date.	On Line of Pipe.	Supplied at date.					Each Inhabitant.	Each Consumer.	Each Tap.
1	Attleboro, Mass.....	8,300	6,800	6,300	109,808,840			306,357	36.2	48.7	
2	Bay City, Mich.....	33,000	20,000	14,000	53,088,095	51,033,957		3,074,968	93.0	219.0	1,661.0
3	Brockton, Mass.....	33,665	30,500	29,200	87,832,298	28,974,855		1,098,560	32.6	37.6	258.8
4	Burlington, Vt.....	16,700	16,300	16,100	87,170,932	32,469,615	36.8	888,083	53.0	55.0	299.0
6	Fall River, Mass....	89,203		86,076				3,166,509	35.5	36.8	
7	Fitchburg, Mass....	26,500	23,000	20,300	58,157,000	286,000,000			94.0	123.0	670.0
8	Lynn, Mass.....	66,861			215,591,850			4,360,142		67.5	
9	Middleboro, Mass...	Town, 7,000 / Fire D. 4,200	4,000	3,700				213,378	51.0	57.7	306.0
10	New Bedford Mass..	56,300	47,076	46,154	18,533,073	251,346,482	16.0	4,711,866	84.0	102.0	587.0
11	New London, Conn.	15,000	14,700	14,000	14,000,000			1,244,320	83.0	89.0	467.3
12	Newton, Mass.....	28,500	28,100	27,900	235,000,000	110,000,000	52.0	1,801,162	63.2	64.2	304.0
13	Oberlin, Ohio.....	4,500	3,500	1,900	4,361,070	2,157,000	23.3	76,700	17.0	40.0	173.0
15	Reading, Mass.....	4,717	4,140	3,550	4,179,920	583,414		198,289	42.03	55.85	263.33
16	Springfield, Mass...	51,534	47,000	41,000	355,608,935		21.0	4,638,060	90.0	113.0	587.0
17	Taunton, Mass.....	27,093	23,700	23,600	57,349,979	123,188,567		1,148,390	42.0	49.0	299.0
18	Waltham, Mass.....	21,000	20,400	20,000	28,120,950				58.5	61.9	402.0
19	Woonsocket, R. I...	28,500	26,000	23,500				621,464	21.8	26.4	336.0
20	Yonkers, N. Y.....	38,000	33,000	32,000	227,754,974	432,882,912	58.2	3,108,400	82.0	94.0	850.0

1895.—IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Distribution Pipe in Inches.	3 Length Extended During Year, Feet.	4 Length Discontinued During Year, Feet.	5 Total Length in Use, Miles.	6 Cost of Repairs Per Mile.	7 Number of Leaks Per Mile.	8 Length of Pipe Less than 4" Diameter, Miles.	9 Hydrants. No. Added.	10 Hydrants. Total in Use.	11 Stop Cocks. No. Added.	12 Stop Cocks. Total in Use.	15 Range of Pressure Pounds.
1	Attleboro, Mass...	C. I. & C. L.	4 to 16	1,660		28.60	$	0.14		2	223			50 to 62
2	Bay City, Mich....	C. I. & Wyckoff.	3 to 20	9,475	3,325	44.	16.01	1.	.06	17	387	23	670	35 to 38
3	Brockton, Mass...	W. I., C. L. & C. I.	6 to 30	24,108	1,210	54.5	4.58	.89		39	488	79	540	47 to 56
4	Burlington, Vt ...	C. L., W. I. & C. I.	4 to 24	7,433	3,515	35.65	30.	1.4	2.8	8	195	38	486	70 to 85
5	Concord, N. H ..			8,798		56.3				4	243	19	682	
6	Fall River, Mass..	C. I.	6 to 24			76.1				37	780	28	776	80
7	Fitchburg, Mass ..	W. I., C. L. & C. I.	2 to 30	10,938		59.34	6.78	.28	1.54	19	408	13	442	155 to 160 75 to 80
8	Lynn, Mass.....	W. I., C. L. & C. I.	2 to 20	6,304		124.		1.3		3	786	11	931	50 to 65
9	Middleboro, Mass.	C. I.	4 to 12	2,075		14.				3	102	10	140	45 to 60
10	New Bedford, Mass	W. I. C. L. & C. I.	4 to 30	31,080	22,453	76.3	13.88		1.1	17	624	29	864	29 to 38
11	N. London, Conn.	W. I., C. L. & C. I.	4 to 20	7,858		43.1	10.60	.7	2.9	5	198	8	227	45 to 50
12	Newton, Mass ..	C. I.	4 to 20	34,576		120.	15.23	.09	2.8	45	805	41	643	84
13	Oberlin, Ohio.....	C. I.	4 to 12	1,121		7.8	1.40	.25	.3	2	72	1	45	27 to 32
14	Plymouth, Mass..	W. I. & C. L.	2 to 20	4,879½		34.	5.30	.1	10.5	1	106	5	312	
15	Reading, Mass....	C. I.	4 to 12	1,976		20.4	none	none	none	3	111	3	193	68 to 78
16	Springfield, Mass.	W. I., C. L. & C. I.	¾ to 36	39,194	5,182	123.6	6.03	.41	7.9	76	793	133	1,440	100 to 120 30 to 35
17	Taunton, Mass ...	C. I.	4 to 20	1,393		70.7	25.33		1.2	24	705	14	480	45 to 50
18	Waltham, Mass...	C. I. & C. L.	2 to 24	3,010		47.8	8 10	.5		10	281	17	602	56
19	Woonsocket, R. I.	C. I.	4 to 20	3,690		37.	2.92	.43	0	5	462	10	397	90 to 115
20	Yonkers, N. Y. . .	C. I.	4 to 30	36,406		56.7	26.00	1.5	0	59	582	35	364	

1895.—V.—DISTRIBUTION—SERVICE PIPES.

Number.	Name of City or Town.	16	17	18	19	20	21	22	23	24	25	26a	26b	27	28
		Service Pipe.					Service Taps.				Meters.			Motors and Elevators.	
		Kind of Pipe.	Size of Pipe in Inches.	Length Extended Feet.	Length Discontinued Feet.	Length in Use. Miles.	No. Added.	Total in Use.	Av. Length of Service.	Av. Cost of Service.	Number added.	Now in Use. Domestic.	Now in Use. Manufacturing.	No. added.	Total in Use.
1	Attleboro, Mass...						14	1,851		$	20	619			1
2	Bay City, Mich....	Lead, W. I. & Wyckoff.	¾ to 8								43	559			
3	Brockton, Mass....	W. I., L. L., C. L & C. I.	¾ to 6	16,640	263.	20.7	371	4,245	43.3	8.32	485	2,963			
4	Burlington, Vt ..	Gal. I. and Lead.	¾ to 6	3,739	56.	16.	134	2,969	27.9	9.00	179	1,186	75	3	29
5	Concord, N. H....			2,185		13.5		3,055							
6	Fall River, Mass...	Lead.	½ to 2				308	6,372			325	5,212			
7	Fitchburg, Mass...	W. I., C. L. & C. I.	¾ to 8	6,338		42.8	140	3,876	58.0	14.06	231	1,652	126	11	66
8	Lynn, Mass.....	W. I., C. L., Gal., Ada.	¾ to 10	14,204	3,850.	89.	279	11,023			316	1,206			
9	Middleboro, Mass.	L., W. I. lined with C.	¾ to 2	1,431		7.8	27	697	55.0		17	240	16	0	5
10	New Bedford, Mass	Lead and Cast Iron.	½ to 8	11,043	324.	50.16	260	8,027	42.0	10.52	33	196	58	11	79
11	New London, Ct. .	W. I., C. L., G., L., C. I.	½ to 4	2,408		9.7	108	2,663	22.3	10.85	9	167			22
12	Newton, Mass. ..	Lead, W. I. and C. I.	½ to 6	22,490	4,250.	67.8	332	5,917	62.0	12.90	400	4,557	23		16
13	Oberlin, Ohio.....	Gal. and Lead.	¾ to 1				44	443	25.0	8.00	35	127	10	0	0
14	Plymouth, Mass...	Lead and Cem't Lined.	½ to 1	192		5½	43	1,620	17⅝	3.04					1
15	Reading, Mass ..	G. I., C. L., L. L. & C. I.	¾ to 6	4,943	none	9.3	69	753	71.0	30.83	45	87		2	4
16	Springfield, Mass..	W. I. and C. I.	¾ to 6				418	7,900			260	2,207		18	162
17	Taunton, Mass ...	Cem't L. and W. I.	¾ to 3		5,352.76	37.1	95	3,843		18.68	56	1,228	138	1	14
18	Waltham, Mass....	C. I. & W. C. L.	¾ to 6	3,485	75.	33.8	43	3,035	72.4	36.85	0	72		0	6
19	Woonsocket, R. I.	Lead and Iron.	¾ to 6	1,749			93	1,760	18.6	11.43	84	1,469	42		6
20	Yonkers, N. Y....	Lead and C. I.	¾ to 8				210	3,650			224	3,590	116	1	9

STATISTICS FOR 1896.

Number.	Name of City or Town.	Date of Con'uction.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. Coal Used.	Per Ct. Ashes.	Price per Ton of 2240 Lbs.
1	Attleboro, Mass.....	1873	Circular Well near River.	Pump to S. P.	Blake & Deane.	Bituminous.		$4.60
2	Bay City, Mich.....	1872	Lake Huron.	Pump Direct	Holly.	Coal Slack.	8.76	4.77
3	Brockton, Mass.....	1880	Storage Reservoir	Pump to S. P.	Worthing'n & Holly.	Bituminous.		
4	Burlington, Vt.....	1867-8	Lake Champlain.	Pumping.	Worthington.	Anthracite.		4.65-5.10-5.35
5	Fitchburg, Mass.....		Storage Reservoirs.	Gravitation.				
6	Lynn, Mass.....	187 0	Storage Reservoirs.	Pump to R.	Leavitt & Loretz.	Bituminous.		4.14
7	Middleboro, Mass...	1885	Large Well.	Pump to S. P.	Deane.	Bituminous.		4.50
8	New Bedford, Mass..	1866-9	Storage Reservoir.	Gravity and Pump.	McAlpine & Worthington	Bituminous.	8½	4.00
9	New London, Conn..	1872	Storage Reservoir.	Grav. & Pump by Water Motor	(Lang & Goodhue)			
10	Newton, Mass.....	1875	Filter Basin Springs & Wells.	Pump to R.	Blake & Worthington.	Bituminous.	6.00	4.18
11	Oberlin, Ohio.....	1887	Vermillion River.	Pump to S. P.	Deane.	Bituminous.		2.25
12	Plymouth, Mass.....	1855	Great and Little South and Lout Ponds.	Gravity and P.	Worthington.	Bituminous.		4.75
13	Reading, Mass.....	1890	Filter Gallery.	Pump to S. P.	Blake.	Bituminous.		4.80 4.90
14	Springfield, Mass..	1864-1873-75	Reservoirs.	Gravitation.				
15	Taunton, Mass.....	1876	Elders Pond.	Gravity and Pump.	Holly & Allis.	Bituminous.		3.85
16	Waltham, Mass.....	1872	Charles River.	Pump to R.	Worthington.	Bituminous.	11.00	4.28
17	Woonsocket, R. I...	1884	Crooks Falls Brook	Pump to Tanks.	Worthington.	Bituminous.	7.00	4.38
18	Yonkers, N. Y.....	1874	Storage Reservoir.	Pump to R. & Tank	Wright & Worthington.	Ant'racite & Bit.	10.5	4.13

Number.	3. Coal Consumed for the Year, Lbs.	4. Lbs. of Wood. 3.	5. Total Fuel Consumed for the Ye'r Lbs.	6. T'l Pump'ge for the Year in Gallons.	7. Av'ge Static Head ag'st Pumps.	8. Av. Dy'mic Head ag'st Pumps, ft.	9. No. Gallons Pumped Per Lb. of Coal.	10. Duty in Ft. Lbs. Per 100 lbs. of Coal, No Deductions.	11. Cost per Mil'on Gal. Pumped into Res'voir Fig. on Pmp. Station Ex's.	12. Cost per Mil. Gals. Rai'd 1 ft. High. Fig. P. Sta. Ex	13. C'st pr Mil. Gals. P'm'd into Res'vr Fig on To'l Main'ance	14. C'st pr Mil Gal. r'sd 1 ft high Fig on Total main'ance
1	455,881	1,000	456,881	115,559,540	160	B175 D188	253	39,750,000	$18.70	$ .0996	$ 143.50	$ .765
2	3,535,760			1,909,523,471		113			7.29	.064	44.42	0.393
3	491,275			397,982,808		43	810.10		5.08	.118	96.00	2.23
4				305,817,025	289	316			34.59	0.109	172.19	0.535
5												
6	1,146,050	300	1,146,350	623,382,276		162.3	543.9	73,607,452	6.55	.0399	79.06	.4816
	1,598,500	600	1,599,100	1,037,462,650		165.25	648.7	89,426,269				
7	473,270		473,270	77,252,570	180	201	165.55	28,199,725	32.11	.16	89.61	.445
8	2,884,200	473	2,884,673	1,975,205,472	125.7	135.6	642	72,355,552	5.72	4.29	38.72	29.04
					141.5	151.52	785	54,999,360				
9					124.9	129.51	435	84,774,912				
10	1,584,800	8,000	1,592,800	666,259,000	234	254	418	111,000,000	12.62	.05	160.84	.63
11	290,000		290,000	24,584,700	80	80	84.8	5,656,000	49.00	.61	190.80	2.38
12	228,100		228,100	105,399,360	66		462.07	25,434,181	15.41	0.2323	90.42	1.37
13	524,703		524,703	72,734,860	219	240	139	3,177,050	43 59	.181	186.78	.778
14												
15	1,011,900		1,011,900	427,437,849		69.83	602.36	34,096,561	10.94	.1567	166.55	2.39
16	2,065,000			555,213,476	165	186	270	42,810,750	12.00	.063	69.15	.0304
											101.36	
17	953,000	258	953,774	259,015,107	238	239	271	54,198,946	14.90	.062	117.28	.48
18	4,309,543			1,243,182,067	185		288.4		11.00			

1896.—II.—FINANCIAL.

Number.	Name of City or Town.	Receipts from Consumers.				
		A	B	C	D	E
		Rates Domestic.	Rates Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.
1	Attleboro, Mass	$	$	$ 15,292.29	$	$
2	Bay City, Mich	17,322.88	5,741.98	23,064.86	159.10	22,223.96
3	Brockton, Mass	40,333.16	9,174.69	49,507.85	183.04	49,690.89
4	Burlington, Vt	36,513.32	4,621.78	41,135.10	1,896.08	43,031.18
5	Fitchburg, Mass	51,204.66	13,968.33	65,172.39		
6	Lynn, Mass	128,047.11	48,768.51	176,815.62	9,357.83	186.173.45
7	Middleboro, Mass	7,751.65	2,741.65	10,439.30	76.79	10,570.09
8	New Bedford, Mass	85,866.74	8,290.33	94,157.07	103.00	94,260.07
9	New London, Conn			41,104.39		41,104.39
10	Newton, Mass	78,958.71	5,300.00	96,641.98		
11	Oberlin, Ohio	3,584.21	380.00	3,964.21	644.96	4,609.17
12	Plymouth, Mass	15,455.17	1,397.25	16,852.42	235.29	17,087.71
13	Reading, Mass	7,346.24	137.75	7,483.99	70.31	7,554.30
14	Springfield, Mass	129,175.52	55,222.65	184,398.17	24,148 39	208,546.56
15	Taunton, Mass	38,541.69	10,836.86	49,378.55	310.12	49,688.67
16	Waltham, Mass	52,395.11	6,504.16		1,605.28	60,504.55
17	Woonsocket, R. I.	29,373.13	7,834.38	37,207.51	101.21	37,308.72
18	Yonkers, N. Y.	83,019.73	26,757.39		5,009.91	

1896.—II.—FINANCIAL.—Continued.

Number.	Receipts from Public Funds.					K	AA	BB		
	F	G	H	I	J					
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.	Gross Receipts.	Management and Repairs.	Interest on Bonds.	Miscellaneous Expenses.	Total Maintenance.
1	$ 6,488.00	$ 375.00	$	$ 287.00		$ 22,484.23	$ 4,552.10	$ 10,984.03	$ 982.58	$ 16,518.71
2					$ 26,110.00	49,333.96	18,731.58	26,110.00		44,841.58
3	3,000.00					52,690.89	8,736.39	29,725.00		38,461.39
4	3,360.00		1,889.91	6,069.91	3,557.07	52,658.16	42,008,16	10,650.00		52,658.16
5							14,740.00			40,530.33
6							58,005.82	73,346.24		131,352.06
7					2,000.00	12,570.09	4,222.44	2,700.00		4,222.44
8					46,883.33	141,143.40	29,588.85	46,883.33		76,472.18
9					24,540.00	41,104.39	5,712.52	24,540.00		30,252.52
10	15,200 00	130.00	2,700.00	950.00	120.00	116,605.98	17,271.52	89,900.00		17,271.52
11					2,700,00	7,309.17	2,092 70	2,600.00		4,692.70
12						17,087.71	5,466.07	4,065.60		9,531.67
13	3,330.00				4,570.00	15,454.30	5,617.21	7,968.53		13.585,74
14	16,820.00	1,491.80	4,975.58	4,073.95	25.000.00	261,822.89	21,022.95	96,000.00		124,660.15
15	3.500.00	1,794.79	800,00	532.06		76,897.15	21,292.01	49,893.00		71,185.01
16						60,504.55	21,872.80	16,520.00		38,392.80
17	41,642.50	1,467.26	2,096.26	851.16	11,000,00	67,365.90	11,124.39	19,254.71		30,379,10
18	18,210.00				2,035 53	135,032.56	37,067.02	73,950.00	21,828.03	

1896.—III.—CONSUMPTION.

Number.	Name of City or Town.	1	2	3	5	6	Percentage of Total Consumption Metered.	7	8	9	10
		Estimated Population.			Quantity used through Domestic Meters—Gals.	Quantity used through Man'f'ring Meters—Gals.		Average Daily Consumption, Gallons.	Gallons per Day.		
		Total at Date.	On Line of Pipe.	Supplied at date.					Each Inhabitant.	Each Consumer.	Each Tap.
1	Attleboro, Mass.....	8,500	7,000	6,500	115,559,540			315,612	37.1		48.5
2	Bay City, Mich.....	33,000	20,000	14,000	53,762,412	52,977,831	10.57	2,758,261	83.0	197.0	1,484.0
3	Brockton, Mass.....	35,000	32,000	31,000	116,536,470	40,604,662		1,087,111	31.06	34.90	239.80
4	Burlington, Vt.....	17,300	16,900	16,700	107,786,961	18,291,510		835,565	48.0	50.0	272.0
5	Fitchburg, Mass....	26,500	23,000	20,300	56,900,000	279,000,000			94.0	123.0	670.0
6	Lynn, Mass.....	69,361		67,139	249,906,830			4,551,789		67.8	
7	Middleboro, Mass...	Fire D. 4,200 / 7,000	4,000	3,700					50.25	57.0	292.0
8	New Bedford Mass..	59,000	49,530	45,570	40,475,088	316,760,610		5,259,017	89.0	108.0	623.0
9	New London, Conn.	15,500	15,000	14,500				1,385,134	89.0	95.5	505.0
10	Newton, Mass.....	29,500	29,100	28,900	275,000,000	55,000,000		1,812,484	614.10	627.10	289.0
11	Oberlin, Ohio.....	4,600	3,500	2,000	6,000,000	1,900,000	33.0	67,200	14.6	33.6	143.0
12	Plymouth, Mass....										
13	Reading, Mass.....	4,750	4,160	3,600	5,545,170	1,031,483		199,273	41.95	47.89	245.41
14	Springfield, Mass...	54,812	48,800	42,500	372,253,326		21.0	4,819,828	88.0	113.0	581.0
15	Taunton, Mass.....	27,093	26,700	26,361	51,276,720	92,735,534		1,167,863	43.0	44.0	296.0
16	Waltham, Mass.....	21,500	21,000	20,500	33,441,260			1,521,133	70.0	72.0	490.0
17	Woonsocket, R. I...	28,500	26,500	26,500				708,227	24.9	26.7	359.0
18	Yonkers, N. Y.....	40,000	34,000	33,000	248,223,254	365,141,844	50.3	3,331,802	83.0	100.0	910.0

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Distribution Pipe in Inches.	3 Length Extended During Year, Feet.	4 Length Discontinued During Year, Feet.	5 Total Length in Use, Miles.	6 Cost of Repairs Per Mile.	7 Number of Leaks Per Mile.	8 Length of Pipe Less than 4" Diameter, Miles.	9 Hydrants. No. Added.	10 Hydrants. Total in Use.	11 Stop Cocks. No. Added.	12 Stop Cocks. Total in Use.	15 Range of Pressure Pounds.
1	Attleboro, Mass...	C. I. & C. L.	4 to 16	5,210		29.58	$	0.13		11	234			50 to 62
2	Bay City, Mich....	C. I. & Wyckoff.	3 to 20	2,554	6,830	43.25	13.63	1.	.06	6	393		662	35 to 38
3	Brockton, Mass...	W. I., C. L. & C. I.	6 to 30	14,714.3	25	56.84	3.26	.56		31	519	36	576	47 to 56
4	Burlington, Vt....	C. L., C. I. & W. I.	4 to 24	9,992	8,051	36.	9.	.75	14.619	7	202	27	513	70 to 85
5	Fitchburg, Mass..	W. I., C. L. & C. I.	2 to 30	14,168		62.09	5.32		1.54	17	425	16	458	155 to 160 75 to 80
6	Lynn, Mass.....	W. I., C. L. & C. I.	2 to 20	2,659		108.8		146.		3	170	5	936	50 to 65
7	Middleboro, Mass.	C. I.	4 to 12	8,010.8		15⅝				6	108	8	148	45 to 60
8	New Bedford, Mass	W. I. C. L. & C. I.	4 to 36	51,259	8,358	84.4116	9.80	14.	6,420 ft	46	670	65	928	26 to 44
9	N. London, Conn.	W. I., C. L. & C. I.	4 to 20	8,623		44.7	18.46	1.	2.04	9	207	19	246	45 to 50
10	Newton, Mass...	C. I.	4 to 20	29,874		125 7/10	16.06	13.	2.9	35	840	41	684	84
11	Oberlin, Ohio.....	C. I.	4 to 12	1,730		8.1			.33	2	74	3	48	27 to 32
12	Plymouth, Mass..	W. I. & C. L.	2 to 20	668		34.	9.38	1.	10.5	3	116	7	319	
13	Reading, Mass...	C. I.	4 to 12	666		20.0412					111	2	195	68 to 78
14	Springfield, Mass.	W. I., C. L. & C. I.	¾ to 36	30,351	8,415	127.8	11.69	.42	39,779 ft	48	841	105	1,545	100 to 120 30 to 35
15	Taunton, Mass ...	C. I.	4 to 20	4,349		71.56	29.85	4.	6,415 ft	19	724	9	492	45 to 50
16	Waltham, Mass...	C. I., W. I. & C. L.	2 to 24	1,951		48.1	6.57	1.		10	291	21	623	58
17	Woonsocket, R. I.	C. I.	4 to 20	9,028		42.6	1.76	.23		23	514	19	416	90 to 115
18	Yonkers, N. Y....	C. I.	3 to 30	11,163		60.8	19.00	1.5	.84	18	628	9	373	

1896.—V.—DISTRIBUTION—SERVICE PIPES.

Number.	Name of City or Town.	16	17	18	19	20	21	22	23	24	25	26a	26b	27	28
		Service Pipe.					Service Taps.				Meters.			Motors and Elevators.	
		Kind of Pipe.	Size of Pipe in Inches.	Length Extended Feet.	Length Discontinued Feet.	Length in Use. Miles.	No. Added.	Total in Use.	Av. Length of Service.	Av. Cost of Service.	Number added.	Now in Use. Domestic.	Now in Use. Manufac'ing.	No. added.	Total in Use.
1	Attleboro, Mass...		⅝ to 8				7	1,858		$	54		673		1
2	Bay City, Mich....	Lead, W. I. & Wyckoff.	¾ to 6	18,586	433.	24.17	336	4,581		9.06	61	620			
3	Brockton, Mass....	W. I., L. L., C. L & C. I.	¾ to 6	3,241	211.	16.5	98	3,067	32.34	9.17	419	3,382			
4	Burlington, Vt ..	Gal., Lead.	¾ to 8	6,197		44.06	175	4,051	35.	11.20	291	1,501	51	1	30
5	Fitchburg, Mass...	W. I., C. L. & C. I.	¾ to 10	11,116	925.	90.9	264	11,267			93	1,695	176	4	70
6	Lynn, Mass.....	L., C. L., Ada. Gal., L. L.	¾ to 3	1,201		42469f	25	722	50.		355	1,561			
7	Middleboro, Mass.	L., W. I. and C. L.	¾ to 10	15,718	412.	53.06	420	8,447	36.	15.01	17	254	19		5
8	New Bedford, Mass	Lead and Cast Iron.	¾ to 4	1,725		10.	78	2,741	19.	13.74	112	307	59	2	81
9	New London, Ct. .	G. I., Gal., C. L. and L.	¾ to 6	23,097	5,828.	71.	359	6,276	61.	25.50	20	187		1	23
10	Newton, Mass. ..	Lead, W. I. and C. I.	¾ to 2				28	471	25.	8.00	443	4,958	25	1	17
11	Oberlin, Ohio.....	Gal., Lead.	¾ to 1	423		5 5	43	1,664	17⅝	4.50	37	169	5	0	0
12	Plymouth, Mass...	Lead and Cem't Lined.	¾ to 6	4,881		10.27	59	812	82.7	26.58					1
13	Reading, Mass ..	G. I., C. L., L. L. & C. I	¾ to 6				398	8,298			48	135		0	3
14	Springfield, Mass..	W. I. and C. I.	¾ to 3	1.18m	5,723.42	38.33	119	3,955		19.47	92	2,299			172
15	Taunton, Mass....	Cem't L. and W. I.	¾ to 8	4,139	464.	34.1	43	3,085	70.5	24.85	76	1,443	1,297	0	14
16	Waltham, Mass....	C. I. W. I. & C. L.	¾ to 6	1,787		5.5	112	1,872	17.2	12.78	3	75		0	6
17	Woonsocket, R. I.	Lead and Iron.	¾ to 8				266	3,790			88	1,552	47	3	9
18	Yonkers, N. Y.....	Lead and C. I.									256	3,836	126		9

PROCEEDINGS.

MONTHLY MEETING.

YOUNG'S HOTEL,
Boston, February 9, 1898.

President Kent in the chair. Members and guests were present as follows:

ACTIVE MEMBERS.

Everett L. Abbott, Solon M. Allis, Francis E. Appleton, Charles H. Baldwin, Lewis M. Bancroft, R. S. Bartlett, George E. Batchelder, Joseph E. Beals, James F. Bigelow, Dexter Brackett, John T. Cavanagh, George F. Chace, E. J. Chadbourne, Charles E. Chandler, William F. Codd, Freeman C. Coffin, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, F. H. Crandall, A. A. Forbes, F. F. Forbes, E. N. French, Frank L. Fuller, J. C. Gilbert, Albert S. Glover, J. A. Gould, E. H. Gowing, Francis C. Green, E. A. W. Hammatt, George W. Harrington, John C. Haskell, F. S. Hollis, Horace G. Holden, Willard Kent, Patrick Kieran, Frank E. Merrill, Leonard Metcalf, Charles F. Murphy, Frank L. Northrop, W. H. Richards, W. W. Robertson, A. H. Salisbury, George A. Stacy, Edwin A. Taylor, Lucian A. Taylor, W. H. Thomas, D. N. Tower, Charles K. Walker, Wm. W. Wade, John C. Whitney, G. E. Winslow, E. T. Wiswall.

ASSOCIATE MEMBERS.

Chadwick Lead Works, by A. H. Brodrick.
Deane Steam Pump Co., by Messrs. Hayes and Bellows.
Ludlow Manufacturing Co., by H. F. Gould.
Hersey Manufacturing Co., by J. Edward Spofford.
Henry F. Jenks, Pawtucket, R. I.
Lead Lined Pipe Co.,
Neptune Meter Co., by H. H. Kinsey.
Perrin, Seamans & Co., by H. L. Bowd.
Rensselaer Manufacturing Co., by F. S. Bates.
Builders' Iron Foundry, Providence, R. I., by T. C. Clifford.
Anthony P. Smith, by W. H. Van Winkle.
Union Water Meter Co., by F. L. Northrop.
R. D. Wood & Co., by Jesse Garrett.
H. R. Worthington, by J. M. Betton.

GUESTS.

Norris J. Alton, Calvin Claflin, J. J. Moore, W. E. Maybury, J. W. McGeary, L. B. Palmer and H. L. Thomas.

The following named gentlemen were elected resident active members:

Benjamin R. Chapman, Civil Engineer, Brockton, Mass.; J. F. Gleason, Foreman of Construction, Quincy, Mass.

The first paper of the afternoon was read by F. H. Crandall, Superintendent, Burlington, Vermont, his subject being "Loss of Water from Pipes." Mr. Brackett, Mr. Whitney, Mr. Richards, Mr. Kieran, Mr. Stacy, Mr. Holden and Mr. Fuller took part in the discussion which followed.

Mr. H. G. Holden, Superintendent, Nashua, N. H., gave a description of the laying of a 24-inch main under the Nashua river. Experiences in similar work were told by Messrs. Crandall, Gowing, Brackett and Gilbert.

Mr. Solon M. Allis, of Malden, Mass., read a paper entitled, "Experiences in the Arid Southwest."

The meeting then adjourned.

QUARTERLY MEETING.

YOUNG'S HOTEL,
Boston, March 9, 1898.

The following members and guests were present:

ACTIVE MEMBERS.

Francis E. Appleton, George E. Batchelder, Joseph E. Beals, George Bowers, Dexter Brackett, John T. Cavanagh, George F. Chace, E. J. Chadbourne, G. L. Chapin, John C. Chase, Harry W. Clark, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, George K. Crandall, Lucus Cushing, O. A. Doane, John W. Ellis, B. R. Felton, Charles R. Felton, E. N. French, Alphonse Fteley, Frank L. Fuller, J. C. Gilbert, J. F. Gleason, T. C. Gleason, Albert S. Glover, Frederick W. Gow, James H. Harlow, John C. Haskell, T. G. Hazard, Jr., F. S. Hollis, H. N. Hyde, Willard Kent, Frank C. Kimball, James W. Locke, Frank E. Merrill, Leonard Metcalf, Edward C. Nichols, Frank L. Northrop, Edward Phillips, J. B. Putnam, Walter H. Richards, W. W. Robertson, William T. Sedgwick, John E. Smith, George A. Stacy, J. D. Hardy, J. A. St. Louis, Charles H. Swan, Wm. H. Thomas, W. H. Vaughan, Charles K. Walker, William W. Wade, J. Alfred Welch, John C. Whitney, George E. Winslow, E. T. Wiswall, M. N. Baker.

ASSOCIATE MEMBERS.

Coffin Valve Co., by Mr. Weston.
Deane Steam Pump Co., by F. H. Hayes and L. E. Bellows, General Manager.
Drummond, M. J., New York City, N. Y., by W. G. Briggs.
George E. Gilchrist, by H. M. Libbey.
Mellin S. Harlow, Boston, Mass.
Kennedy Valve Co.
Hersey Manufacturing Co., by Albert S. Glover.
The Hydraulic Construction Co., by M. R. Ryder.
Jenks, Henry F., Pawtucket, R. I.
The McNeal Pipe and Foundry Co., by I. S. Haines, Treasurer.
Lead Lined Pipe Co., by T. E. Dwyer.
National Meter Co., by J. Edward Spofford.
Neptune Meter Co., by H. H. Kinsey.
Perrin, Seamans & Co., by H. L. Bond.
Rensselaer Manufacturing Co., by F. S. Bates.
Builders' Iron Foundry, by T. C. Clifford.
Anthony P. Smith, by W. H. Van Winkle.
Sumner & Goodwin Co., by F. D. Sumner.
Union Water Meter Co., by J. P. K. Otis.
R. D. Wood & Co., by Mr. Newhall.
H. R. Worthington, by J. M. Betton.

GUESTS.

C. M. Ames, C. F. Chase, F. B. Endicott, C. E. Fowler and G. L. Turner.

The following named gentlemen were elected active resident members:

George E. Manning, C. E., New London, Conn.
William Walter Ewell, Supt. Water Works, Quincy.
J. D. Hardy, Supt. Holyoke Water Works.
James L. Tighe, Engineer, Holyoke Water Works.
Charles D. Colson, Water Commissioner, Holyoke.
Thomas F. Greaney, Water Commissioner, Holyoke.
John J. Sullivan, Water Commissioner, Holyoke.

Charles E. Fowler, Superintendent and Engineer of the Poughkeepsie Water Works, read a paper entitled "Operation of a Slow Sand Filter." The subject was discussed by Mr. Hazen, Mr. Clark, Mr. Haskell and Prof. Sedgwick.

On motion of the Secretary the thanks of the Association were extended to Mr. Fowler for his paper.

Adjourned.

OBITUARY.

WILLIAM M. HAWES.—Died February 16th, 1898, aged 65 years. Joined this Association June 16th, 1886.

Mr. Hawes was for many years a member of the Board of Water Commissioners of the city of Fall River, Mass., and as such took an active interest in the welfare of this Association. He was a constant attendant at its meetings until stricken with the disease which finally resulted in his death. His genial good fellowship and kindly disposition won the friendship of all the members of the Association by whom his death is sincerely mourned.